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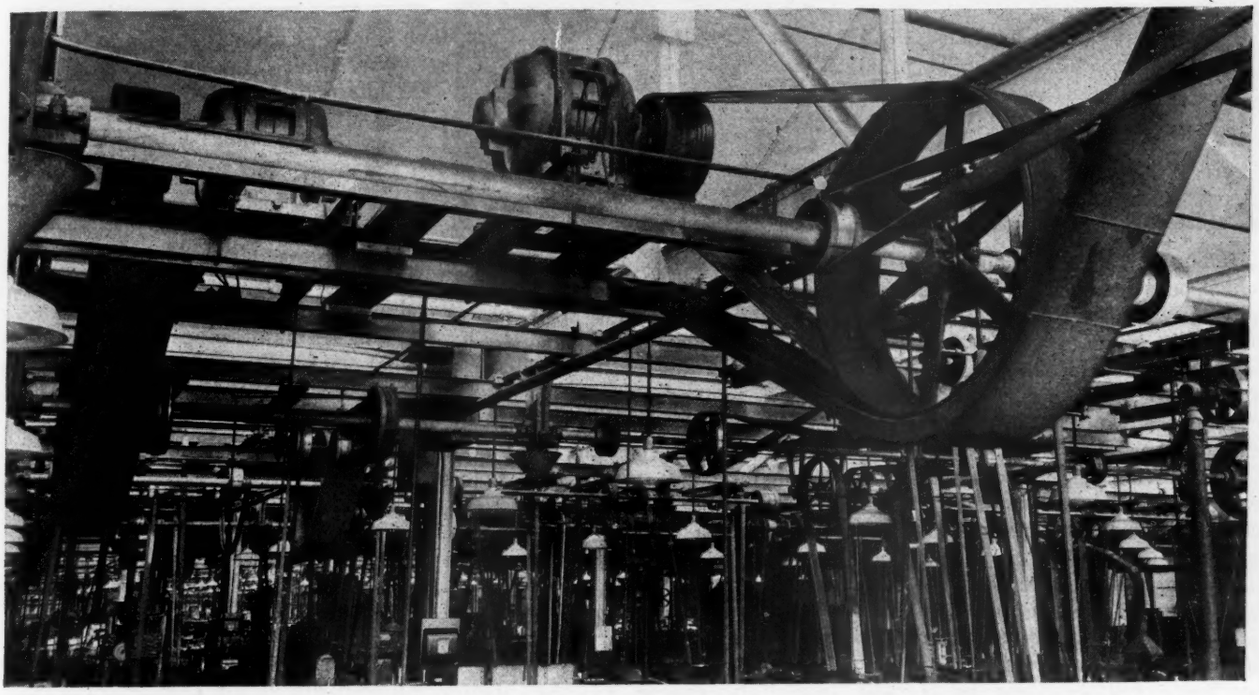

Method of mounting lineshafts and drives is standardized

Maintenance work can be done in less time when the mill-wrighting in the shop is standardized because the workers know from experience exactly how the work can be done easily and quickly and also anticipate the need for any necessary tools or supplies. Whenever a gang has to change a motor or lineshaft they can go prepared for the job and not have to "run back to the shop" several times for something that has been overlooked.

Some results obtained by

Applying a Bonus Plan to Maintenance Work

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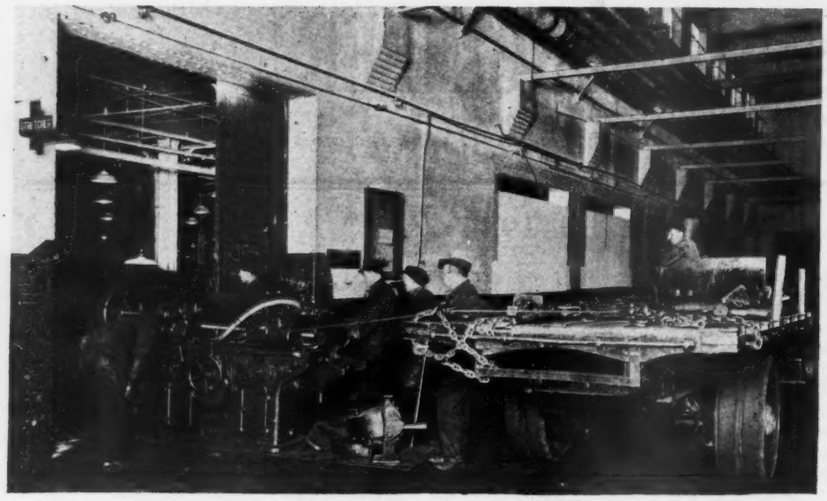
TO BE adequately understood, any discussion of our bonus system as applied to our Maintenance Department must necessarily include certain fundamental facts concerning our bonus as applied to the direct work as a whole.

Our maintenance problems are those of a manufacturing plant as opposed to an assembly plant, as we build all of our engines, axles, and transmissions and do all of the machining of the parts. We make a high-grade product, necessitating exacting work in our manufacturing divisions, which calls for the employment of highly-skilled labor. Our plant extends over an area of 35 acres and has approximately 1,600,000 sq.ft. of floor space, so that our maintenance requirements are of a wide variety.

In 1921, when the various production departments were put on a production bonus plan, it soon became evident that we could further our plans for the application of scientific management principles to our plant, by extending the production bonus plan to include the various units of indirect labor. To fully comprehend this application of our bonus system to our Maintenance Department, however, we must first summarize the features of our bonus system as applied to our direct production departments.

Under our plan, all jobs are classified, so that jobs requiring equal ability and the same degree of skill will be paid equal bonus, regardless of the department in which they happen to be located. For the purpose of computing bonus pay all jobs are divided into ten classes. Bonus Class 1 pays 25 cents for a standard 8-hr. day at 100 per cent efficiency. Continuing in jumps of 25 cents per class per standard 8-hr. day, the bonus increases to $2.50 per standard 8-hr. day for bonus Class 10 for 100 per cent efficiency.



One of the activities of the Yards and Ways Department.

Miscellaneous heavy work, such as moving machinery, can be handled to better advantage if good facilities are provided for doing it. In this case a truck with a winch is being used to pull a machine up the narrow shop aisle on rollers and out into the service bay onto a large sheet of steel which serves as a skid. Small machines are often moved on lift truck platforms. The prospect of a bonus is an incentive to the men to use their initiative to speed up the job.

Bonus is paid only for good pieces which pass inspection. It is paid in addition to, and entirely independent, of hourly wages. We go so far as to pay our bonus in separate envelopes so as to maintain this independence, and to encourage the saving of the bonus money.

The worker begins to earn bonus when his efficiency reaches 60 per cent, and as his efficiency increases, his earnings increase proportionately as far as his skill and energy will permit him to go. Should he work less than the standard 8-hr. day, his bonus is computed on the same basis as for a full day, and he is paid bonus proportionately for the time he works, whether it be one hour or eight.

In studying the question of applying a bonus system to our indirect labor, we naturally considered the fundamental principles underlying our production bonus plan. We began consideration of its application to our Maintenance Department about three years ago, when our cost records began to show that the cost of our Maintenance Department per truck unit did not decrease with increasing truck production. Furthermore, continuous production is dependent on continuous operation of equipment, and we wanted to put the maintenance of production equipment on as firm a foundation as that of production itself. These two facts, coupled with the constant requests of the maintenance men for a bonus system similar to that in the production departments, provided the impetus for our study of the situation.

Our maintenance group is organized under the general supervision of the Plant Engineer, and under the immediate charge of the Master Mechanic. The group includes maintenance proper, steam, air and power equipment, janitors and watchmen, yards and ways, garages, locomotives and cranes, refrigeration, and general.

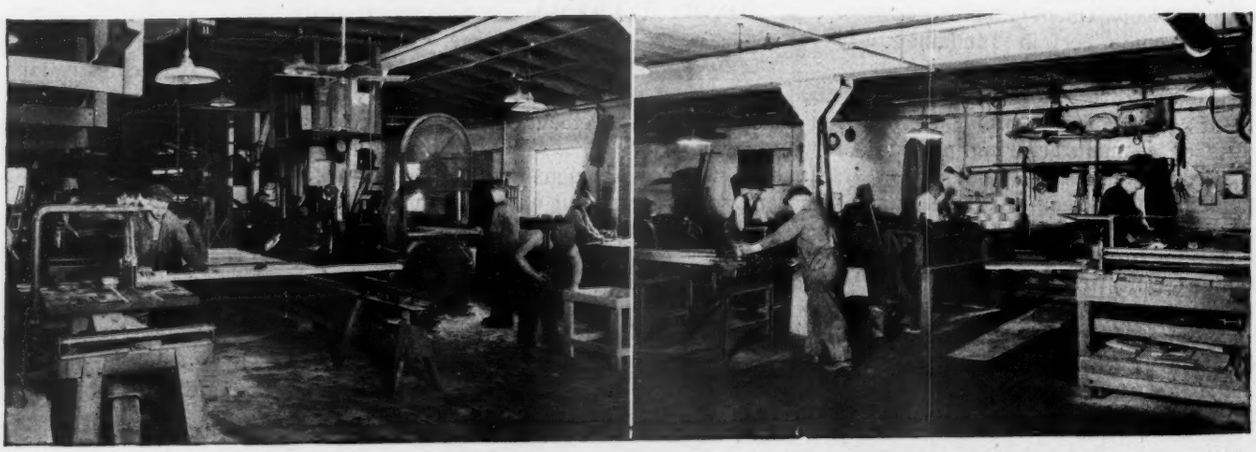
These plant services are usually the ones included in Plant Engineering and are classified as indirect labor; they are seldom considered as coming within that group of activities which can be estimated or predetermined closely enough to place on a time schedule or under a bonus system.

However, we thought that our basic fundamentals were sound and determined to try to develop a bonus plan for the Maintenance Department. We decided that any plan adopted must consider those elements of maintenance work which could be individually time-studied and placed on individual bonus as were all of our production jobs.

This was the first step, and after an analysis had been made of all of the jobs in the Maintenance Department they were classified into two groups: first, those which could be individually time-studied and, second, those which seemed to be applicable to some sort of a group plan.

We then started out to get as close an estimate of the general efficiency of that part of the Maintenance Division as we could under the group plan and then devise a means of measuring this efficiency. We proceeded in about this manner: We assigned, for example, three trained time-study observers to study three plumbers. On alternate days each observer recorded everything which his man did during the day. In this way we obtained three independent observations of each plumber.

The observers reported that on an average the plumbers worked about



Both the carpenter shop (left) and the sheet metal shop (right) are used for maintenance work only.

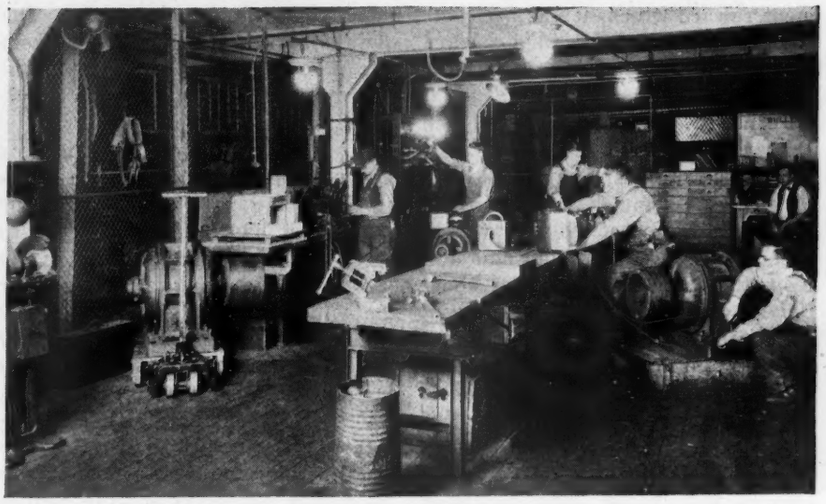
70 per cent of the time. The remaining 30 per cent was spent either in idle time or in unnecessary movement. In other words, we found that our plumbers at the factory were just about the same as those we call to our homes. They went to the job first and looked it over; then returned to their base of operation to get their tools.

In general, investigations in a large number of plants by various authorities who have made a study of wage incentive plans, show that men working without extra wage incentives will have an efficiency of about 50 per cent. The loss of 50 per cent in efficiency is due to unnecessary or unplanned time, or to a poor method of doing the work. For the first two the men themselves are responsible, and for the last case the management is responsible. When we first adopted the bonus system in 1921, we made it a part of our job to see that adequate provision was made to provide the proper equipment to perform the work by the very best methods. We have tried to adhere strictly to this policy.

The procedure for plumbers was followed through for carpenters, electricians and others to whom this method could be reasonably applied. Having determined the relative efficiency of the men in the maintenance group, our next step was to ascertain the maintenance force required for any given volume of production.

The first step was to determine what were the minimum requirements. For this purpose we assumed the plant to be shut down to zero production and boarded up for at least a year. Then by employing our judgment as to the reasonable precautions required for adequately protecting our property under these conditions, we figured out the number of men necessary to keep on our maintenance payroll. Both winter and summer schedules were set up to take care of the difference in the number of men required during winter as compared to those necessary during the summer. The summer schedule begins with the first of May and ends with the last day of September. The winter schedule covers the other months.

Without going through the details of determining the number of watchmen, carpenters, clean-up men, and others necessary to guard the plant and care for the small office force



One end of the electrical repair shop.

Extensive rewinding jobs are practically all sent outside. Motors are handled more easily and quickly by putting them on platforms and moving them with a lift truck. All motors are provided with a pulley which will give the proper reduction to the standardized lineshaft speed anywhere in the shop.

necessary under the conditions outlined, the net results were that we found we would require a force of 40 men in summer and 44 men in winter.

By making use of our records of different maintenance forces employed at various production schedules, we then worked out a curve which gave us the man-hours required for almost any rate of production. This, of course, was with our maintenance men working at 100 per cent efficiency. Correlating all of our information, we obtained the maintenance man-hours applicable to a single truck unit. Adjusting this figure again for gross plant operation, figured at 80 per cent efficiency, we now had a figure which represented the maintenance man-hours required to produce a truck unit.

With the information now available, it was a simple matter to incorporate our findings in a table which represents man-hours at various efficiencies required to maintain various production schedules. This table is the basis for figuring all bonus pay.

It was evident that to obtain the largest saving possible it would be necessary to secure co-ordination and co-operation between all of the men in the maintenance group. The functions and activities of this group are so overlapping that it was not feasible to attempt to make any fine distinctions as to proper division of work. For this reason it was decided to make the group large and include all of the divisions of the Plant Engineer's group in our bonus calculations. This gave not only each group but also each member of each group a definite incentive to co-operate and co-ordinate his work with that of the others. Therefore, on January 1, 1924, we put our maintenance department as a whole on the bonus plan.

A certain few details merit some explanation at this time. The discussion following, or preceding, however, cannot be considered exhaustive. This discussion as it is written is designed to be of general interest. With this in mind, then, certain detailed information essential to putting such a plan into effect has been omitted as not properly belonging to considerations only of general interest.

It is of interest to know, however, that new construction work which does not exceed 10 per cent of the allowance in standard hours for all maintenance work, must be included with this department's regular activities. New construction work exceeding the 10 per cent allowance is handled through contracts with outside concerns.

Bonus for janitors, scrub women, and others whose work can be time-studied by ordinary time study methods, is figured daily. Each person receives an individual bonus slip on which, along with other information, is recorded his efficiency and exact bonus pay for the previous day. Those who are subject only to group performance records, receive their bonus slips weekly. These short bonus periods give the worker a fre-

quent reward which, it has been our experience, goes a long ways toward sustaining interest in the bonus—if such were needed.

Formerly about all our watchmen did was to attend strictly to their duties as watchmen, but since they have been included in the bonus group we have noticed one watchman who secured a broom and now keeps the sidewalks swept for about 100 ft. on each side of his shanty. We waited with interest to see what he would do in winter and, sure enough, he kept the snow shoveled off all during the winter. In this way the man who otherwise would have to keep the walk clean, is left free to put in his time profitably elsewhere.

A good example of the manner in which our bonus system has inspired increased efficiency is in the case of our painters. Painting, being an operation which can be time-studied, was placed on bonus on a time-area basis. In establishing this, consideration was given to the different types of work, such as the location, structure and amount of time required to cover and uncover the machinery or floor. Practically all of the painting work is done by the use of an air gun. We paint the interior of our factory on an average of about once in every three years. As our factory buildings are practically all single-story structures, much of the ceiling painting is in saw-tooth roofs. To help the men in their work we have devised an extension arm about 8 ft. long to which the gun is attached and operated by a wire. This enables the painter to spray almost the entire ceiling with a minimum amount of scaffolding or staging. The saving in time which resulted from this was, of course, taken into consideration in determining the standard time for the work.

However, the painters themselves showed ingenuity in devising methods of increasing their efficiency. For example, it had been the practice to stage or climb up into the peak of the saw-tooth and hang a canvas over the windows to prevent the spray settling on the glass. They have now fastened the canvas to a rod like a curtain and push it up into the peak, where it is held in position by uprights cut to the proper length. This protects the windows. Also, it was frequently necessary for the men to cover machines or stock to prevent spray from settling on them. Now, however, they suspend the canvas from the ceiling in much the same manner as is done to protect the windows, thereby increasing their efficiency considerably.

A question which we are frequently asked is, "If the men receive a bonus on the saving of time on a job, what is there to prevent them from rushing it through as quickly as possible, even though they might know that a few minutes saved now will mean more minutes in repairs later?" It has been our policy to retain men in our employ regularly. We take considerable pride in the service records of our employees. The men know or soon find out that it is not the single job which they do that gives them their bonus, but the accumulated savings on many jobs through a long period of time. They expect to be on the job a month or a year from today and so they do not want to risk the chance of losing their bonus at that period through false economy now. Maintenance and service must come first and the bonus will follow naturally.

When a bonus plan of this sort is in effect, the men object strenuously to hiring extra help unless they see that it is absolutely necessary. This is because the extra man-hours will go into the total hours worked, to compare against the standard hours. This, of course, decreases the departmental efficiency, and so decreases their individual bonus. Thus each man has a definite incentive to do as much work as possible himself, and to keep the number of men in the department down to a minimum. The men soon notice if one of their members does not put in his best efforts. In such a case they do not hesitate to let him know about it, thus taking care of the situation themselves.

The work of the Yards and Ways Department is very hard to schedule. It also varies largely with production and, therefore, has been included in a general plan on the unit production basis. Many novel methods of moving heavy machinery have been inaugurated, one of which is shown in an accompanying illustration.

In the final analysis, before the efficiency of watchmen, maintenance men and others whose efficiency cannot be computed on a time area-basis can be calculated, the efficiency of those whose work can be so measured is computed. Then the standard hours allowed and the actual hours required for the work of janitors, painters, and so on, are subtracted from the respective figures for the whole maintenance group. The remaining figures for standard hours allowed and actual hours required are the basis for computing the efficiency of watchmen, maintenance men and others whose work is dependent on the efficiency of the whole group.

It is apparent that janitors, painters, and so on, have an individual incentive for reaching a high

This view shows a section of the pipe shop at the White Motor Company.

One of the important wastes of time under the former plan was caused by unnecessary trips between the shop and the job. When the men are working under a bonus plan they anticipate their needs and make fewer trips, which gives them much more time for productive work on the job.

efficiency, because they are paid according to their individual performance. There is also a definite incentive for watchmen, maintenance men and the others to help them with their work and to help them cut down the number of men, because the efficiency of the former is dependent upon the efficiency of the latter.

A discussion such as this normally inspires two questions: First, is the plan successful and, second, to what is its success attributed? We regard the plan as successful. It has been a distinct benefit to the workmen and has been an aid to the management.

In substantiation of the statement that it appeals to employees, little more need be said than that it provides them increased wages, good working conditions, steady employment, and a chance for individual recognition.

At the time of the first pay period after its installation the efficiency of the group was 67 per cent, from which point it has gradually risen to an average well above 90 per cent. This department itself is somewhat responsible for working conditions, and with the incentive provided for doing their work, naturally these conditions have been very much improved.

Unusually low labor turnover testifies to the steady employment which the system assures. And in the separate envelope in which bonus is paid semi-monthly, each man receives individual recognition of his work during the previous period.

One of the chief features of our bonus system is that the supervising heads of departments and the group heads, as well, receive a bonus pay based directly on their departments' efficiency. Naturally this gives them ample incentive to keep their efficiency as high as possible. Furthermore, before the plan had been long in operation, it developed that foremen and workmen themselves spontaneously developed what we might call "preventive maintenance," for the lack of a better name.

Before the advent of the bonus plan it was not unusual, for example, for repair men to have a number of jobs waiting for their attention. But now these men go out and check up to see how things are running so they can make repairs before breakdowns occur. This spirit of prevention is in evidence throughout the whole department and probably is quite an element in keeping up the efficiency of the men themselves, and of the department.

This attitude has naturally lowered costs, but what is almost equally important from a production standpoint, it has provided more efficient operation of production equipment. The co-operation and co-ordination referred to heretofore, have been important elements in elevating the spirits and morale of the men in the department.

A humorous illustration of this occurred one night during cleaning hours in one of the offices. It seems that one of the scrub women of a group of four was opposed to the bonus plan, and finally succeeded in winning one other to her side. The other two who worked hard to raise their efficiency had to share the rewards with the recalcitrants and finally engaged them in a pitched battle in order to obtain co-operation. Needless to say, when employees compel co-operation among themselves, a plan which fosters such co-operation is of direct benefit to the management.

We regard the successful operation of the plan as being due to the following characteristics:

First, the plan itself is fundamentally sound. It is reasonable in every respect and is based on logical study of all the elements involved in the situation.

Second, it satisfies both workmen and employer. The extension of parallel studies, modified according to the demands of the situation, to our tool room and our material handling division, which is really another story, at least gives an indication of the manner in which the operation of the plan has been received by all concerned.

The third, and by far the most important, reason why our plan has been successful, is one for the lack of which most unscientific plans have been unsuccessful. Every bonus chart which we issue carries this guarantee: "These bonus prices will not be lowered no matter how long the job may run with this equipment and by the method and design specified in the instruction referred to in the foregoing."

This guarantee never has been and never will be violated. It is the basis for the success of the whole system. Our men believe in it and in us. And when there is that relationship between employer and employee, success should come to both.

Proper Method of Lubricating Wire Rope

PRACTICALLY all the cores of good brands of wire rope, both the preformed and non-preformed types are thoroughly impregnated with a commercial, chemically-neutral rope oil. Although the core retains a liberal supply of this lubricant which gradually oozes out as the rope is used, frequent application of a good lubricant during service is necessary to prevent the core from becoming dry.

A wire rope having a dry core will both wear and crush quicker or will absorb moisture with the result that the core will deteriorate rapidly and the inner wires will corrode, with shortened rope service as the result.

The smaller the sheaves or the heavier the tension on the rope, the more often should the rope be lubricated so as to prevent too rapid wearing of the core in the first case, and excessive crushing in the latter case.

A good lubricant retards corrosion of the wires and deterioration of the core, reduces internal friction which is a cause of wires breaking from increased bending stresses, and decreases external wear. The lubricant should be thin enough to penetrate the strands and the core but not so thin as to run off the rope, nor so thick that it merely covers the rope.

Therefore, a thicker semi-plastic compound applied *hot* in a thinned condition is best to use wherever possible. It will penetrate while hot and then cool to a plastic filler, excluding the entrance of water, and both preserving and lubricating the inner wires and cores of the steel cable.

To properly lubricate with a heated lubricant, it is necessary to have the rope run slowly through the heated tank of oil so that proper penetration takes place. Where this is not possiple, an application of a thinner, unheated lubricant will give better practical results than many other methods now used for rope lubrication.

The American Cable Co. strongly advocates the practice of lubricating the rope just after installation and before running in service, particularly when such ropes have been kept in storage for some time as spares for mine, dredge or other outdoor work where service conditions are severe.

Here is an instance where the light-colored walls help to conserve the light. Even with this direct-illumination system, the white ceiling reflects some of the light. The reflecting value of the ceiling is very important when daylight is available.

What it pays to know about

Lighting Value of Paint in Industrial Plants

including a discussion of the reflection factor and other properties which affect its value, with pointers that will aid in using it most effectively

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WHEN we compute the amount of light lost through neglect in painting surfaces or in maintaining them at high reflection factors we find the result to be staggering. In addition, there are many other reasons for giving proper attention to the painting of walls and ceilings.

Light surroundings are helpful in reducing glare. A light source which is glaring when viewed against a dark background may be rendered satisfactory when viewed against a bright background. The impression of bad lighting has often been created by approved lighting equipment when used with dark surroundings, even though adequate intensities of illumination were delivered to the working plane. Light surroundings are cheerful and stimulating. Disorderliness and dirtiness are far less prevalent amid light surroundings. Both natural and artificial lighting are aided if the interiors of buildings, and the objects therein, are light in color.

The amount of light reflected from a surface is dependent on the color of the surface. If it is dark or dirty the amount of light reflected may be only a few per cent, whereas the best white paints reflect from 80 to 85 per cent of the light incident upon them. The illumination intensities generally found in the interiors of our work places are far below those which are economically practicable. For this reason alone every possible means should be utilized to conserve the light generated by the lighting system.

Paints exhibit the same reflecting characteristics that surfaces do in general. Regular or specular reflection is that of a perfect mirror where the angle of reflection equals the angle of incidence of the rays of light. This condition is approached by polished metals and the surface of glossy varnish. A thick, smooth coating of glossy varnish on a jet black surface is a very good mirror. Such surfaces are undesirable from the viewpoint of lighting because they reflect images of the light sources, thereby causing glare and cther attendant effects, such as visual discomfort, eye strain and reduced visibility. Glossy desk tops, glossy walls and ceilings, and various polished surfaces are possible sources of glare.

Paints with a dull finish closely approach perfect diffuse reflection,

although semi-matte finishes reflect not only diffusely but superimposed on this is a sort of regular reflection. A painted surface coated with glossy varnish, or an enameled surface, also exhibits a combination of diffuse and regular reflection.

The measurement of reflection factor (ratio of total reflected to total incident light) is now a comparatively simple matter in a properly equipped laboratory, but accurate results can be obtained only with a proper instrument. Usually a color difference is involved and results obtained outside the laboratory are far from accurate. Furthermore, the reflection factor of a surface depends upon the direction and distribution of the incident light in all cases excepting that of a perfectly diffusing surface.

In general, walls and ceiling play a part in the distribution and quantity of light to the work plane, but the part they play depends not only upon their reflection factor, but also upon the character of the lighting system. In other words, the walls and ceiling can influence the lighting only insofar as they have an opportunity; this is a matter of the percentage of the total light which is incident upon them. In addition, there are many objects in the interiors of our buildings which absorb light, and even the best white walls and ceilings usually do not reflect more than 80 per cent of the incident light. It is impracticable to attempt to keep the floors highly reflecting and, furthermore, white surroundings do not by any means present the most desirable conditions from the viewpoint of eye comfort and the best vision. When considered from all angles, it is questionable whether the walls directly in the field of view should have a reflection factor greater than 50 per cent.

In the case of direct lighting with opaque, white enameled or silvered glass reflectors, little light reaches the ceiling directly; so its reflection factor when artificial lighting is employed is of little importance, although it is of great importance in the utilization of day light coming through the windows. In the case of indirect lighting and so-called semi-indirect lighting, a large percentage of the light is emitted upward toward the ceiling and, therefore, the reflection factor is important. Walls are important from the standpoint of reflection factor, in proportion to the percentage of light that impinges upon them. Obviously, in large rooms they are of much less importance than in small rooms. They are generally of much greater importance in natural lighting from windows, than when artificial lighting is employed.

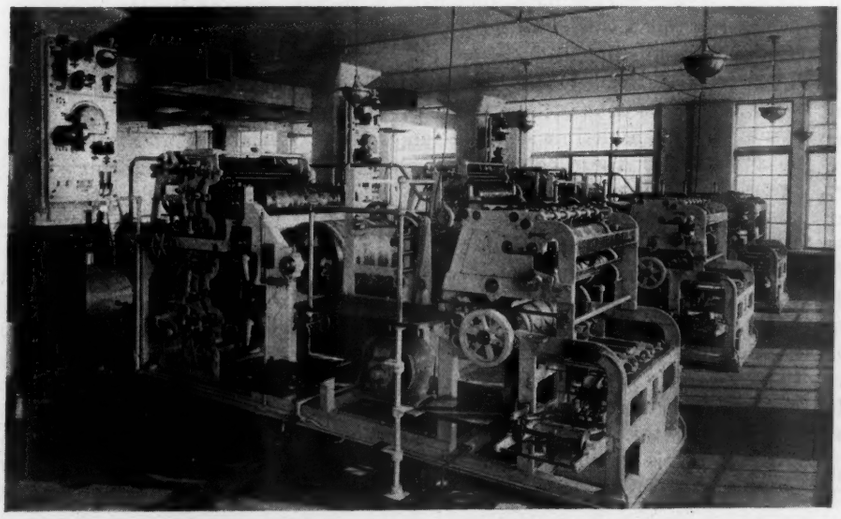
The influence of the reflection factors of ceilings and walls in artificial light is shown in the accompanying table, for three different types of lighting systems and for three sizes of rooms. The lighting equipment is assumed to be hung 10 ft. above the horizontal work plane upon which the relative values of illumination from a certain number of lamps are shown in the table. These data were deduced from the work of E. A. Anderson[1] on utilization factors. The numbers following the words "ceiling" and "walls" are the respective reflection factors. The direct lighting system is one in which approved white enameled or silverized glass reflectors are used. The second system employs approved, enclosed, diffusing-glass equipment. The indirect system is one in which approved, silvered glass or very dense opal glass bowls are used.

The data in the table will bear considerable study. In the large rooms the walls play an important part and it is interesting to note in item (*A*), for example, the effect of the walls as the room size diminishes. This feature is conspicuous in all the items. The ceiling plays a small part in the case of direct lighting with opaque reflectors. This is seen by comparing item (*B*) with item (*D*) where the walls have the same reflection factors, but those of the ceiling are 70 and 30 per cent respectively.

Enclosed, diffusing-glass equipment emits a large amount of light upward to the ceiling and outward to the walls. This is quite evident by the generally lower values of relative illumination under this system than under the direct lighting system. Both the ceiling and the walls influence the relative foot-candle values on the work plane. By comparing (*F*), (*G*), and (*H*), the influence of the reflection factor of the wall is seen. By comparing (*G*) and (*I*), or (*H*) and (*J*), the influence of the reflection factor of the ceiling is seen. There are several outstanding features in this table, of which the following may be mentioned: (1) The appreciable influence of walls of small rooms or narrow rooms in which direct lighting opaque reflectors are used. (2) The great influence of both walls and ceiling in all of the rooms, but particularly those of small and intermediate sizes in the case of lighting systems that employ enclosing, diffusing-glass equipment. (3) The very great influence of walls, and particularly ceilings, in the case of indirect lighting systems; that is, in systems in which most or all of the light is emitted upward by the lighting equipment. These various items present adequate proof of the lighting value of paint.

Manufacturers of machinery have persisted in painting machines and other equipment either black or a very dark color. This practice not only contributes to the cheerlessness of poorly illuminated factories, but

[1]Illumination Design Data, E. A. Anderson, Bulletin 41 National Lamp Works of General Electric Co., Jan. 15, 1921.



In this case painting complicated machines white is an aid in making adjustments and brightens up the room.

even in the modern factory where the lighting is fairly well done, dark machines have a depressing effect and often render the lighting of important areas on the machines exceedingly difficult. The faceplate of a lathe, certain areas of milling machines and particularly complicated machinery such as printing presses can be painted a washable white or light gray and by reflection much light can be thrown on the work, and particularly in the shadows. All machines and equipment should not be painted white. Such a condition would be insufferable. However, if the equipment were painted a very subdued color having a reflection factor of 20 to 25 per cent, much light would be saved by reflection.

The use of glossy paints for interior walls and ceilings is probably due to the belief that flat paints accumulate and retain more dirt than do gloss surfaces. Tests conducted by H. G. Lima[2] indicate that in a dry interior, in which there was a slow accumulation of dirt, slight differences existed at first between the gloss and flat paints. Continuing the exposure a very slight, and later a very decided contrast, was found. In every case the gloss paint had accumulated more dirt than had the flat paint. Further tests conducted in interiors in which moisture was present, and also on samples tested out-of-doors on the roof, again showed that the gloss paints became dirtier than the flat paints. These results, coupled with the advantages that accrue from a lighting standpoint, surely justify the use of flat interior finishes.

Furthermore, the specular or regular reflection from glossy paints, and more particularly enamels, has led many to believe that these finishes reflect a greater amount of light than do the flat finishes. The amount of light which a glossy varnished surface reflects is independent of the diffuse reflection of the coating beneath this transparent coating. The specular or regular component of the reflected light due to the glossy surface amounts to about 4 per cent when the light strikes the surface perpendicularly. This, however, is generally not an additional 4 per cent over the diffuse reflected light from the coating under the gloss, because most of the vehicles used in producing the gloss are colored slightly yellowish. This colored vehicle surrounding the particles of pigment results in a lowered reflection factor of the pigment and generally the net result is a slightly lower reflection factor for glossy finishes than for flat finishes which have been made up with any given pigment.

[2]Technical Bulletin No. 5, 1924, Pittsburgh Plate Glass Co.

Influence of Reflection Factor on Foot-Candles Obtained Under Various Conditions

Lighting System and Reflection Factors of Ceiling and Walls	Relative Foot-Candles on Work-Plane: Small Room (10 ft. by 30 ft.)	Medium-Sized Room (20 ft. by 50 ft.)	Large Room (100 ft. by 100 ft.)
Direct Lighting System:			
(*A*) Ceiling 70; walls 50	50	90	100
(*B*) Ceiling 70; walls 30	42	86	97
(*C*) Ceiling 70; walls 10	35	81	94
(*D*) Ceiling 30; walls 30	40	84	94
(*E*) Ceiling 30; walls 10	35	81	91
Enclosed Diffusing Glass:			
(*F*) Ceiling 70; walls 50	32	67	80
(*G*) Ceiling 70; walls 30	25	59	74
(*H*) Ceiling 70; walls 10	20	54	68
(*I*) Ceiling 30; walls 30	20	49	58
(*J*) Ceiling 30; walls 10	17	45	55
Indirect Lighting System:			
(*K*) Ceiling 70, walls 50	23	52	65
(*L*) Ceiling 70; walls 30	19	46	60
(*M*) Ceiling 70; walls 10	16	42	55
(*N*) Ceiling 30; walls 30	10	25	32
(*O*) Ceiling 30, walls 10	9	23	29

Inasmuch as white paints play such an important part in the effectiveness of many lighting systems, their specific consideration is of particular value. From a practical viewpoint, reflection factor (both initial and sustained), hiding power, specific gravity, cost, and character of surface are important factors in the choice of the paint to be used.

In recent years many paint manufacturers, realizing the value of highly reflecting paints, have shown marked improvements in their product. Today a number of white paints are available having initial reflection factors of 80 per cent or better. In general, white paints have shown a decreasing reflection factor with age, due to discoloration, but even this characteristic has been improved with certain combinations. White paints having high initial reflection factors vary in their behavior with age, some showing only a moderate loss of reflection factor due to discoloration, while others fall off to values equal to those found with paints having considerably lower initial reflection factors. From this it is seen that the average reflection factor over a given period of time is more important than the initial reflection factor.

While it is obvious that paints having a high reflection factor are desirable for the conservation of light, it can also be shown that a definite waste of money occurs when they are not used. For example, in a drafting room that measures 100 ft. by 20 ft. and is equipped with 20, 300-watt, totally-indirect, silvered glass or very dense opal glass bowls, 16 foot-candles of illumination can be provided on the work plane if the reflection factors of the ceiling and walls are 80 and 40 per cent respectively. With electrical energy at $0.05 per kilowatt-hour the 16 foot-candles are obtained throughout the working plane at a cost of $0.30 per hour. If paint having a reflection factor of 70 per cent, instead of 80 per cent, had been used, we find that only 14 foot-candles are delivered to the working plane; still the full $0.30 per hour is being spent for the electrical energy consumed by the lighting system. This represents a monetary loss equivalent to $0.037 for every hour that the lighting system is in operation.

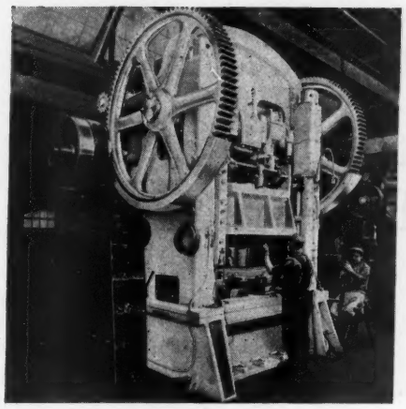
This monetary loss may not seem very significant, but further examination indicates that at the end of 2,400 hr. use of the lighting system, it is equivalent to $90, or the cost of painting the ceiling, assuming that the paint maintained its reflection factor of 70 per cent and no accumulation of dirt had taken place. When lower reflection factors of the ceiling obtain, correspondingly shorter periods of operation of the lighting system effect monetary losses equivalent to the cost of an entire repainting of the ceiling. In fact, this lighting system need be operated only for

810 hr., or nine months, to effect a monetary loss equivalent to the cost of repainting the ceiling, if the reflection factor is 50 per cent throughout that time.

Enclosed, diffusing-glass units are far less dependent on the reflection factor of the ceiling than is the totally indirect system. However, the monetary loss due to light paid for and not received with this type of system in the afore-mentioned interior amounts to the cost of a painting job in approximately 2,700 hr. use of the system if the ceiling reflection factor is 50 per cent. The best reflecting paints may cost appreciably more than the usual paints; however the preceding analysis reveals that the additional expenditure is warranted and will be repaid within a comparatively short time.

Assuming, as a practical standard, the use of a paint having an 80 per cent reflection factor on the ceiling of the above drafting room, which is equipped with a totally-indirect lighting system, any values less than 80 per cent, due to dirt or discoloration, produce a condition of light paid for but not received. This loss, when compared to the cost of repainting, indicates that painting should be done after a period which can be determined easily and more or less definitely.

For a particular installation the solution of the problem involves a number of factors which are generally available. By way of illustration the previously described installation can be used. In this case the most economical period between paintings is approximately 14 mo.



The obstruction to lighting caused by large machines may be greatly reduced by painting them light gray.

The assumptions made in the solution of the problem are as follows:

(1) Initial reflection factor of ceiling and walls is 80 and 40 per cent, respectively.

(2) Location is in an industrial or manufacturing section.

(3) There is a uniform rate of depreciation of ceiling reflection factor of 1.5 points per month; that is, from 80 to 78.5 per cent during the first month, from 78.5 to 77 per cent during the second month, and so on.

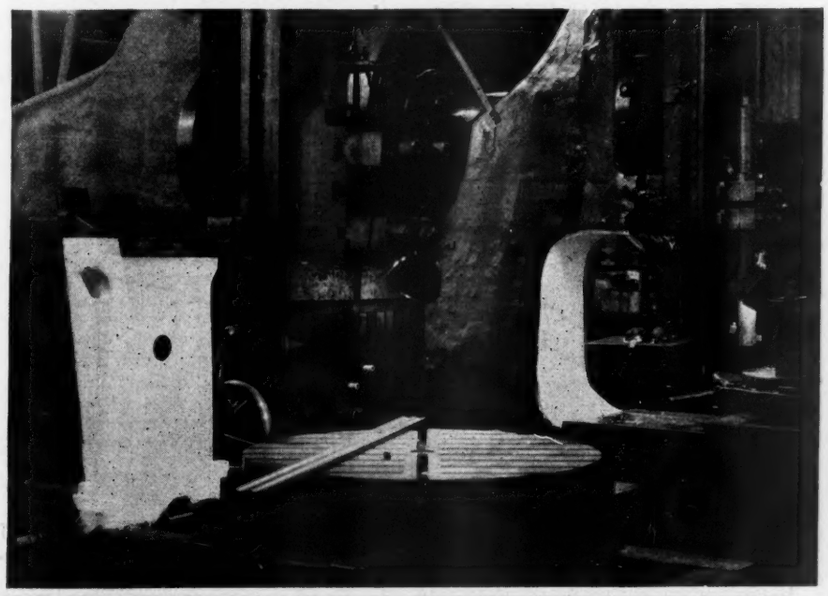
(4) There is no depreciation of wall reflection factor.

(5) Lighting system is used 1,000 hr. per year.

(6) Painting of one heavy coat at $0.40 per square yard, or a total of $90 for the entire ceiling.

(7) Cost of electrical energy is $0.05 per kilowatt-hour.

The application of white paint to certain areas of large machines will help to throw more light onto the work and eliminate shadows.



The time interval between paintings is conservative, as the effect of the walls has not been considered and 1,000 hr. use per year is exceeded by many establishments. Furthermore, no consideration of the visual conditions has been taken into account. During the 14 mo. between paintings the illumination intensity will have decreased from 16 foot-candles to 11 foot-candles. The quickness and accuracy of vision and other visual functions are appreciably different under these intensities. For high-contrast conditions, such as black on white (80 per cent reflection factor), increases in these various visual functions ranging from 4 to 18 per cent have been found when the illumination intensities were raised from 11 to 16 foot-candles. While this factor is difficult to evaluate in terms of production for all industries, still it is of such magnitude as to warrant the attention of all of those who are responsible for production.

The relation between production and intensity of illumination has been carefully studied in industrial plants covering a wide variety of operations, and some of the results obtained were reported in an article by Roy A. Palmer, in the August, 1925, issue of INDUSTRIAL ENGINEER. One of these very interesting tests was conducted at the Timken Roller Bearing Co. plant at Columbus, Ohio. This test, which was conducted in the Inspection Department, extended over several weeks, the high and low levels of illumination being alternated weekly. Inspection work requires fairly close visual application, and the effect of the lighting intensity was shown in a striking manner by the production figures under the low and high levels of illumination. When a high level of illumination was provided, production increased; when the illumination was cut down, production decreased. With each change in the level of illumination the production output obtained responded accordingly.

The intensity in this plant was originally five foot-candles, which is not so low as is found in many plants. The new lighting system installed for the test provided 20 foot-candles. While the five foot-candles of illumination were sufficient for fairly good vision, the new installation helped the speed of vision and produced a stimulating atmosphere in the plant so that production was increased 12.5 per cent.

Raising Power Factor

Without the Use of Corrective Equipment

By JAMES B. HOLSTON

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IN THE preceding article, in the July issue, power factor was considered from the standpoints of what it is, the effects of low power factor and why it is undesirable, and the methods of measuring it. When it is known, or has been determined, that the power factor of an industrial plant is lower than is desired, the next step is to select the best means of raising it.

Low power factor is caused largely by the operation of certain types of electrical equipment at low load factors, Induction motors usually constitute the bulk of an industrial plant load and as the "reactive" or out-of-phase" component of the power in ordinary induction motors is practically the same at no load as at full load, it follows that the reading of the "reactive meter" will be substantially independent of the load on the equipment.

The importance of proper loading of motors is strikingly shown in Fig. 1, which gives the average power factor of squirrel-cage motors, ranging from 1 hp. to 100 hp. in rating, when operated at different percentages of full load. Referring to the curve for the 10-hp. motor, it will be seen that the power factor at 50 per cent load is 61 per cent, and at 75 per cent load it is 74 per cent. Comparatively few applications impose an average load of over 60 per cent of the rating of the motor; hence the effective power factor of the unit will be about 68 per cent.

Many motors are used on machines which operate only intermittently during the day, such as grinders, shears, drill presses and similar equipment. The common belief that the power cost of operating the motors running idle is so small that it may be overlooked, and that such motors need not be shut down when the machines which they drive are not in use, takes no account of power factor effect. As has been stated, the "reactive" meter records practically the same with no load on the motor as at full load; therefore, motors idling on the lines produce as bad an effect on plant power factor as do fully loaded motors. For this reason idle operation of motors should be carefully avoided.

Reference to Fig. 2 brings out the interesting and important fact that the efficiency, as well as the power factor of squirrel-cage motors drops off sharply at loads less than 50 per cent.

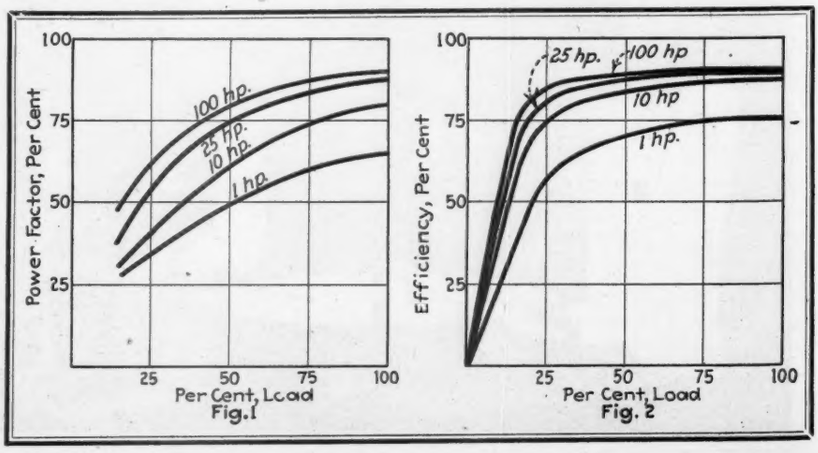
Due to the inherent characteristics of squirrel-cage induction motors, slow-speed or low-horsepower motors have low power factor and low efficiency, while high-speed or large-horsepower motors have high power factor and high efficiency. This fact should be kept in mind when making any rearrangement of motors for power factor correction, or if any new motors are to be installed.

In both Figs. 1 and 2 the performance of 860-r.p.m. motors has been shown, as this speed is widely used. Higher speed motors of the equivalent horsepower ratings will have efficiencies and power factors slightly above those shown.

The foregoing discussion may serve to explain the somewhat paradoxical title of this paper. One solution of the power factor problem clearly lies in eliminating as far as possible those motors that are operating at low power factor. The simplest and most accurate method of locating the improperly loaded units is to make load tests of the input to every motor which operates for any appreciable period of time. Of course, such motors as may be used only very intermittently on cranes, elevators, blowers, fire pumps and similar drives need not be considered, as they have little or no effect on the power factor of a plant.

LOW POWER FACTOR in an industrial plant may be the cause of a number of conditions that are undesirable from an operating standpoint. It may also increase the cost of electrical energy through penalties imposed by the power company. In this article Mr. Holston describes some practical ways in which power factor can be raised to the point where it ceases to be troublesome, without the use of special, corrective equipment. The use of such equipment will be considered in a subsequent article to appear in an early issue.

Details of the procedure and equipment used in making a load survey of this character were given in an article by H. E. Stafford, on page 310 of the July, 1925, issue of INDUSTRIAL ENGINEER. It need only be said here that three meters are required to make these tests: a voltmeter, an ammeter and a wattmeter, together with suitable current transformers. If graphic or recording-type meters are available they should



Figs. 1 and 2—These curves show the approximate average power factor and efficiency of 220-volt, three-phase, 60-cycle, 860-r.p.m. squirrel-cage induction motors when operated at different percentages of full-load rating.

be used, as a permanent record can then be kept, but indicating meters are perfectly satisfactory. These instruments should be mounted on a small truck to facilitate moving them from one location to another. (An ingenious engineer in one industrial plant used a boys' coaster wagon which served the purpose admirably.) Leads soldered to each end of a blown cartridge fuse will be found convenient in making connections to the ammeter and wattmeter, and spring clips on the voltmeter leads will help to simplify the job of connecting up.

The data obtained are best recorded in some such form as shown in Fig. 3 for study after the tests have been completed. Only three readings are taken—volts, amperes and kilowatts—the other values being obtained from the manufacturers of the motors, or calculated from the performance data. If a polyphase wattmeter is used the reading of the meter will be the full input, but if two single-phase meters are used the readings must be added together to obtain the true input. Voltage and current readings may be omitted if desired, as they are not used in the calculations to be made, but should be taken if convenient in order to determine whether the voltage is low or the current drawn by any motor is excessive.

Fig. 3—Here is a convenient method of recording test data on motors to determine whether they are properly loaded.

It is advisable to take three readings—kilowatts, volts and amperes—although the latter two may be omitted if desired. After the data have been recorded and corrected, as shown, the per cent of full-load rating may be found by dividing the observed kilowatt input by the kilowatts taken at full load, as given by the manufacturer.

Referring to Fig. 3, a careful study of the results of these tests, which were made in a large industrial plant, showed that several motors were not properly loaded. For example, blower No. 1 required only about 18 hp. to drive it, while the motor was rated at 25 hp. On the other hand, the machine shop motor was overloaded. By adjusting the pulley sizes these motors were interchanged and a better load on each was the result, with a saving in "reactive" power, as the machine shop motor runs only 7 hr. a day, while the blower runs 24 hr. The motor on blower No. 2 was fairly well loaded.

A check upon the load cycle of the air compressor showed that it was in operation only about one-half of the time. An automatic control to cut off the motor when the air pressure reaches 100 lb. and cut it in when the pressure drops to 80 lb., was installed, and saves a substantial amount of useful as well as reactive power.

The motor-generator set never drew over 20 hp.; hence a new 20-hp. motor was installed and the 35-hp. motor kept as a spare.

Some other changes were made in operating schedules to give more uniform loading of motors, with resulting savings both in "real" and "reactive" power.

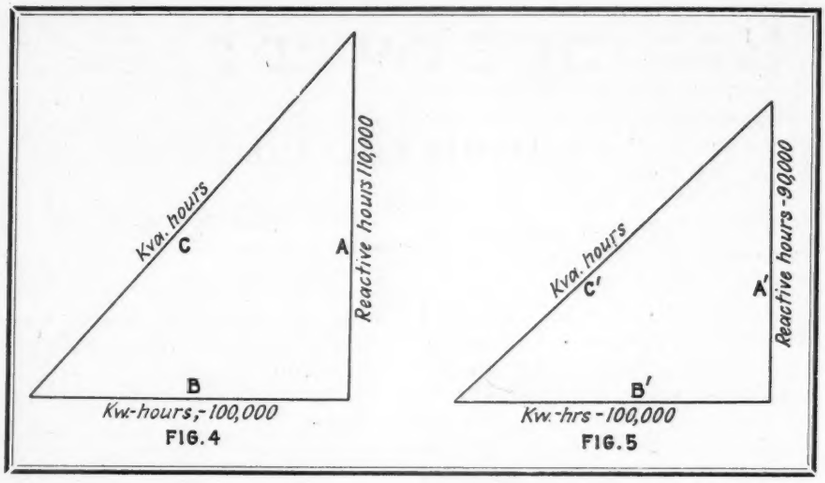
This plant used 100,000 kilowatt-hours per month before the above changes were made and with normal operation registered 110,000 "reactive" hours. Referring to the familiar power factor triangle, shown in Fig. 4, it will be seen that power factor can be determined from these two readings by the use of simple mathematics. As was explained in the preceding article, power factor being defined as the ratio of real to apparent power, it is represented in Fig. 4 by $B \div C$. Knowing the values of A and B, C may be found by taking the square root of the sum of the squares of A and B, which may be expressed as follows:

$$C = \sqrt{A^2 + B^2}$$

In this case A equals 110,000 and B equals 100,000; hence

$$C = \sqrt{(11^2 + 10^2) \times 10^3}$$
$$= \sqrt{221} \times 10{,}000 = 148{,}600$$

Therefore, Power Factor $= B \div C$ $= 100{,}000 \div 148{,}600 = 67.3$ per cent.



Figs. 4 and 5—Relation between kilowatt and reactive hours, before and after rearranging motors in a plant to obtain better loading.

Fig. 4 represents the original condition; power factor ($B \div C$) was 67.3 per cent. From Fig. 5, it will be seen that the reactive hours have been reduced to 90,000, which gives a power factor ($B^1 \div C^1$) of 74.3 per cent.

Motor Test Record

Column (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Drive	Hp.	Test Data			Corrected Data		Mfrs. Data		Per Cent Load *
		Volts	Amps	Kw.	Amps	Kw.	Amps	Kw.	(Col. 7 ÷
			(x 10)	(x 2)	(Using Mult.)		(Full Load)		Col. 9)
Blower No. 1	25	228	4.90	7.7	49	15.4	60	21.1	73.0
Blower No. 2	15	228	3.20	5.5	32	11.0	36	12.7	86.5
Machine Shop Line Shaft	20	227	5.70	9.6	57	19.2	50	16.9	114.0
Air Compressor Pumping	100	227	467x50	39.5	235	79.0	242	82.9	95.3
Idle		230	24x50	18.7	120	37.4			45.0
Motor Generator Set	35	230	5.6	8.6	56	17.2	84	29.4	58.5
Circulating Pump	5	230	12.5	2.0	12.5	4.0	13.9	4.5	89.0
Line Shaft 2nd Floor	25	227	4.5	6.85	45.0	13.7	63	21.1	65.0
3rd. Floor	40	227	7.3	11.8	73.0	23.6	96	33.6	70.0

* Efficiency at loads between 50 and 100 per cent assumed to be the same. See Fig. 2

By rearranging motors to load them more fully, shutting down idle motors whenever possible, and by working out more uniform operating schedules for motors that were running continuously, this plant was able to decrease the "reactive" hours from 110,000 to 90,000. Referring to Fig. 5 it will be seen that the following conditions then existed:

Power Factor $= B^1 \div C^1 =$

$100{,}000 \div \sqrt{(9^2 + 10^2)10^8} =$

$100{,}000 \div 134{,}500 = 74.3$ per cent

The curve shown in Fig. 6 (tangent-cosine curve) affords a short cut in computing power factor from the readings of the kilowatt-hour and "reactive" meters. In the example shown in Fig. 4 the ratio of "reactive" hours to kilowatt-hours is 1.10. Locating on the curve the point of intersection of the vertical line corresponding to 1.10 on the abscissa or horizontal line in Fig. 6, the power factor is found to be 67.3 per cent, which checks with the previous calculations. In the case of Fig. 5 the ratio is 0.90 and the power factor is found to be 74.3 per cent. This chart is very convenient in making calculations of this kind and has been reproduced of sufficiently large size to be accurate enough for all ordinary calculations.

After the changes mentioned above had been made the kilowatt-hour consumption decreased, due to more efficient operation. For simplicity in calculations this fact was not taken into account in the data shown in Fig. 5. However, annealing furnaces of 100-kw. capacity were added, operating 200 hr. per month and thus using 20,000 kw.-hr. As the power factor of this type of equipment is 100 per cent the overall plant power factor was raised, as shown in Fig. 7. Inasmuch as the "reactive" meter continues to record the motor load, but gets no additional reactive hours from the furnaces, it will still read 90,000. The kilowatt-hour meter, however, now records the former load plus the 20,000 kilowatt-hours added by the electric furnace, or 120,000. Using Fig. 6, the ratio of 90,000 to 120,000 is seen to be 0.75, giving a power factor of 80 per cent.

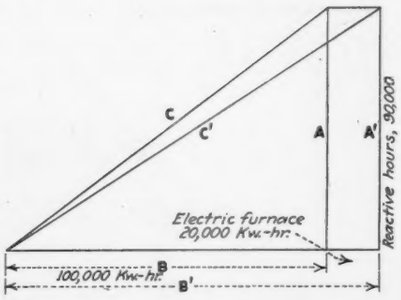


Fig. 7—An electric furnace load will help to raise the power factor of a plant.

After the power factor had been raised to 74.3 per cent, by rearranging motors, the conditions were as represented by the triangle whose sides are shown as *ABC*. The addition of some electrically-heated annealing furnaces increased the energy consumption of the plant 20,000 kw.-hr. a month and created the conditions shown by the triangle whose sides are A^1 B^1 C^1. Then the power factor is represented by $B^1 \div C^1$ which corresponds to 80 per cent.

Fig. 6—When the ratio of reactive hours to kilowatt-hours is known, the power factor can quickly be determined from this curve.

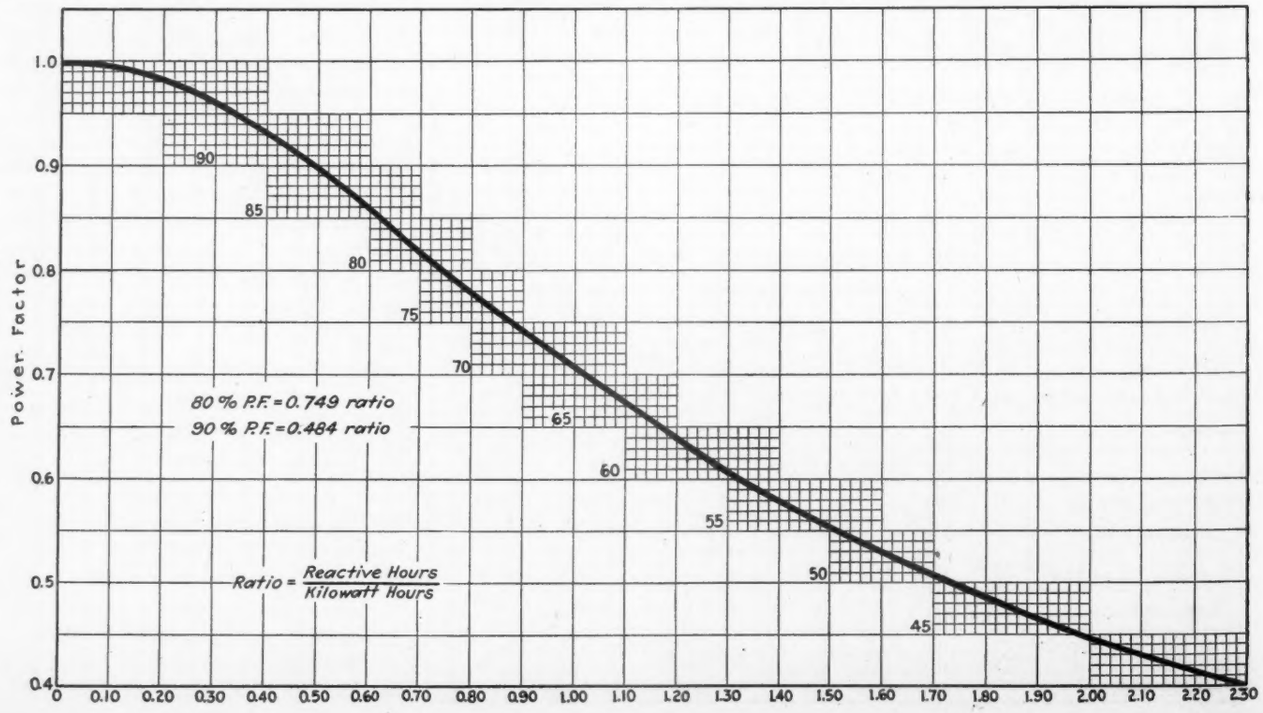
To find the power factor for any given ratio, locate on the curve the point of intersection of the vertical line corresponding to this ratio, as shown on the abscissa or horizontal line. Thus, in the example given in the text, a ratio of 1.10 is found to represent a power factor of about 67 per cent.

Incandescent electric lights and resistance heating equipment of all kinds are unity power factor loads and play an important part in the determination of "effective" monthly power factor. If the addition of either is being considered the effect on the plant power factor, especially if there is a power factor rate, should be taken into account before efforts are made to raise the power factor.

On the other hand, welding equipment and certain types of lighting equipment operate at less than unity power factor and the effect of this load must also be considered.

Probably 80 per cent is about the upper limit of power factor obtainable without the use of corrective equipment in some form, especially where the meters are connected to read the transformer load; but even 80 per cent is far better than the 50 per cent or 60 per cent which is not at all uncommon.

A subsequent article which will appear in an early issue will deal with the various methods of correcting power factor up to a point nearer 100 per cent, or possibly all the way up to 100 per cent, if the savings possible justify it.



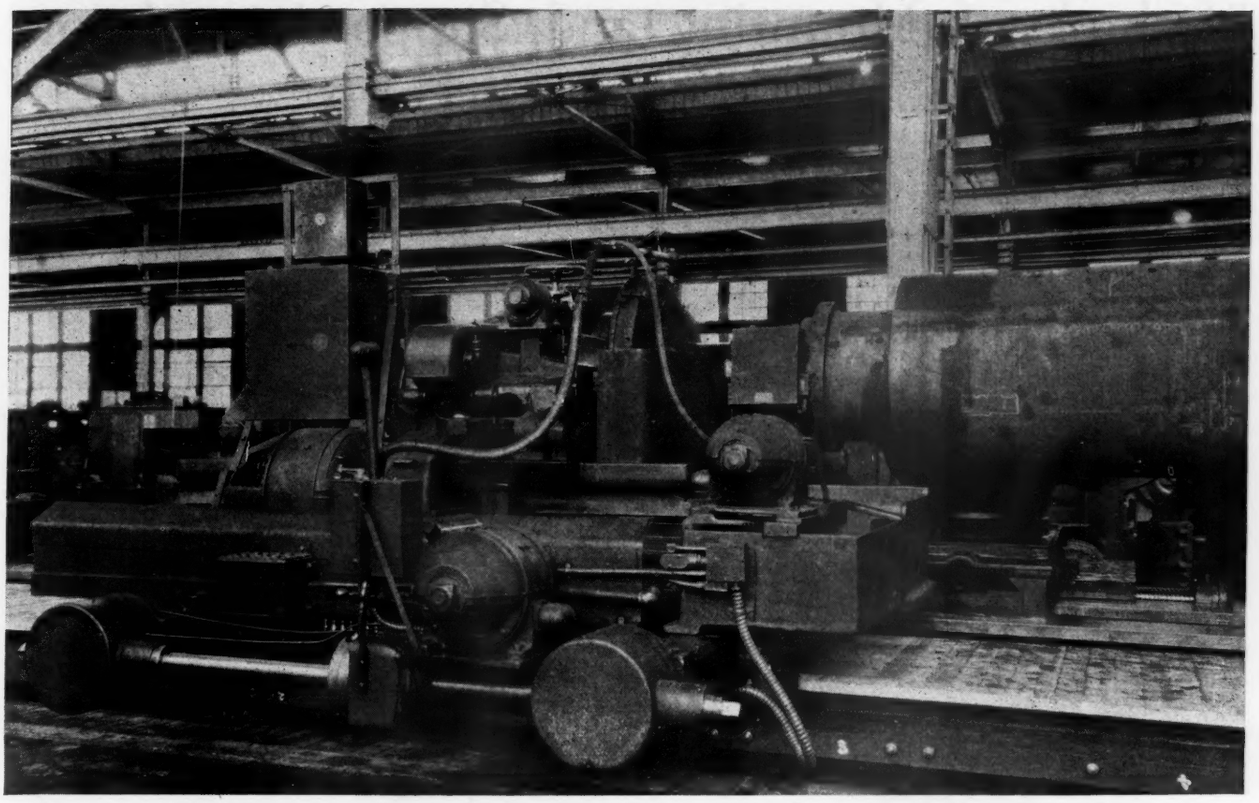


Fig. 1—Here is an excellent method of mounting four motors directly on a 113-in. lathe.

When the driven machine is large with respect to the motor, mounting the motor directly on the machine is very satisfactory. The four motors illustrated here range in size from ½ hp. to 25 hp. and drive different motions of a grinding attachment to a lathe. Some of the motors are mounted directly upon the frame of the lathe, while others are mounted on specially-arranged shelves.

Mounting and Installing Industrial-Type Motors

so as to secure accessibility, reduce vibration, and lower maintenance and repair costs, together with a description of the different types of supports and the relative merits of each

BY GORDON FOX
Electrical Engineer, Freyn Engineering Company, Chicago, Ill.

THE location and manner in which a motor is installed have a great deal to do with the success or failure of a motor drive. Too often a motor is located at a certain place simply because it can be easily bolted down there, with the result that the maintenance and repair charges are excessive. In making a motor installation there are several things that should be considered, the first of which is proper location.

In selecting a location, due regard should be paid to the rules of the National Board of Fire Underwriters and also to any local regulations that may exist. In addition to this, consideration must be given to protection of the motor from moisture, escaping steam, dripping pipes, oil, acid, alkali, chlorine, and other gases, as well as dust, dirt, lint, and other injurious substances. If protection cannot be provided against these troublesome elements, a motor of special construction such as mill type, marine type, splash-proof, force ventilated, and the like should be used. In some cases, particularly with direct-current motors, it may be necessary to build a separate motor room and provide a lineshaft or other form of power transmission to connect the motor to the drive. This is particularly necessary if a direct-current machine is to be used for driving machines placed in a room where any hazardous process is carried on or in places where the motor will be exposed to flammable gases, sawdust, or other combustible material.

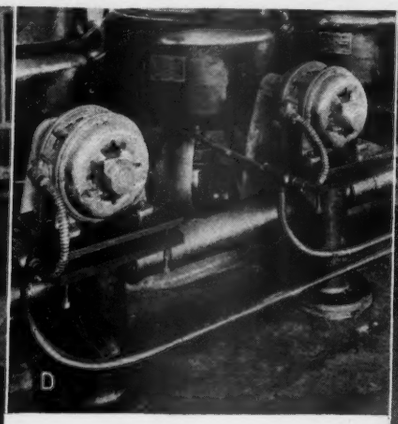
Good ventilation is essential. Motors should not be exposed to excessively high surrounding air temperatures, that is, where the maximum temperature of the windings will be over 90 deg. C.

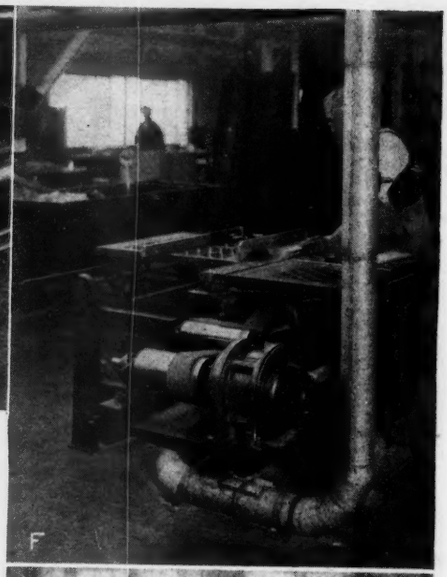
The position of a motor should be such that it is easily accessible for inspection, or else neglect is probable. Clearance spaces should be provided for the removal of the entire motor or its parts. In the case of important machines, care should be exercised to see that broken parts may be quickly replaced. Failing this, the entire motor unit should be exchangeable. It is of advantage to have important motors served by a crane or repair trolley or at least to provide ready means of rigging for handling of motors and parts.

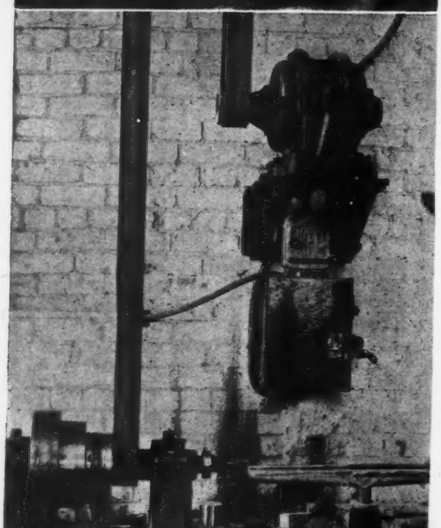
Direct-connected motors are best mounted as an integral part of the driven machine. This is desirable because the machine and drive may then be treated as a unit. It is further desirable for retaining alignment. It is particularly desirable

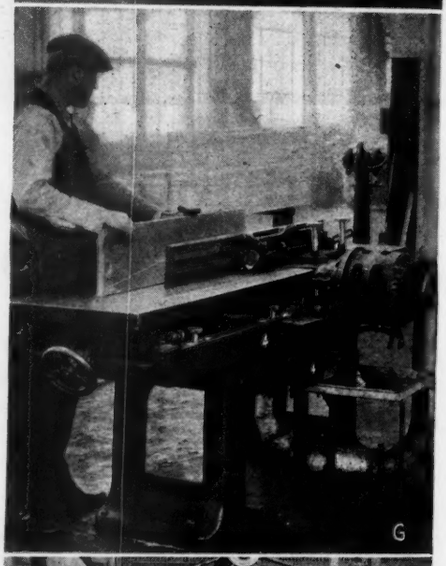
Methods of Mounting and Supporting Motors

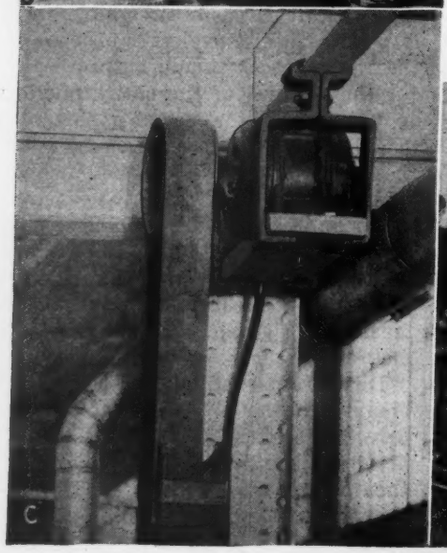
Eight Examples That Have Stood the Test of Service

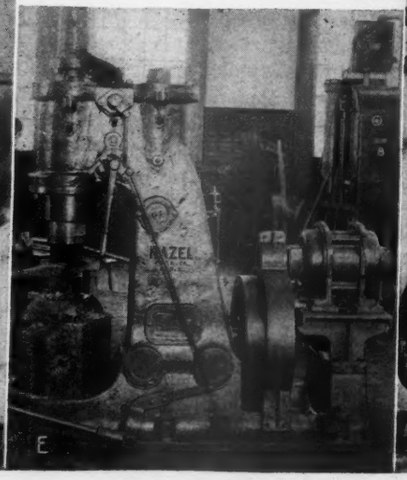


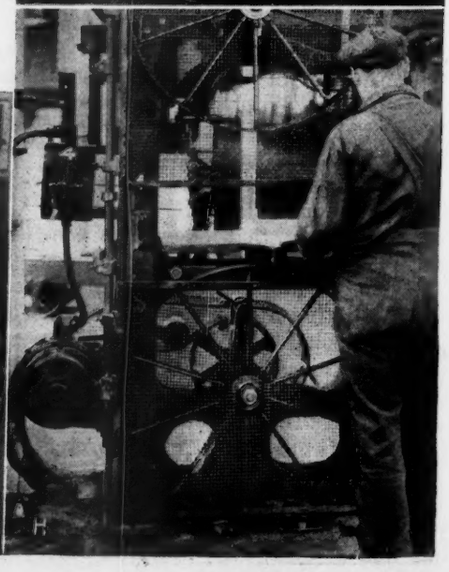












A—Bracket mounting of a small motor that drives a grinder. This arrangement is made up of two angles that are bolted to the flanges of the column. The motor frame is bolted directly to the angles.

B—Bracket mounting of motor on a wall. This mounting is made from steel flats which are bent to the form shown.

C—Clever method of mounting a motor beneath a ceiling I-beam. This support consists of four clamping bars and a wood base fastened together by six bolts.

D—Pedestal mounting of motors to keep them out of the water that usually covers this floor. An angle belt drive is used. As a means of tightening the belt the base may be raised or lowered by four bolts placed at the corners.

E—Another form of pedestal mounting in which the base is integral with the bedplate. Note how accessible the motor is; yet the arrangement is very compact.

F—Compact motor support on a power saw. This support also carries the pedestal bearing required by the wide pulley on the motor.

G—Method of supporting a motor on a high-speed planer. The motor is directly connected to the planer blade and an extra heavy bearing and bracket are provided between the motor and planer to take care of the overhang of the motor.

H—Side mounting of a motor on the frame of a bandsaw. Adjustment of the belt is obtained by an idler pulley.

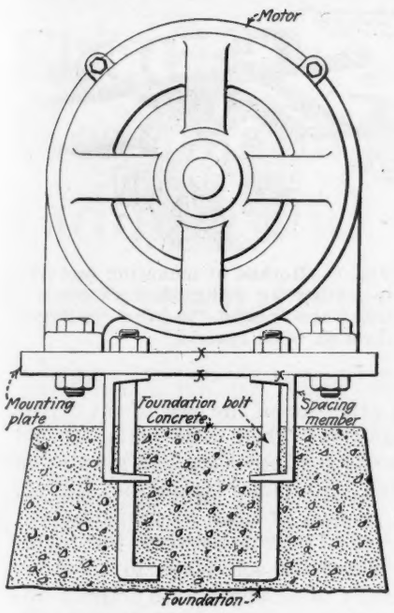


Fig. 2—Mounting on concrete foundation for motor without slide rails.

Two channels are fastened by anchor bolts in a concrete foundation, as shown. Four anchor bolts are used, which also clamp a mounting plate to the channels. With this mounting a motor can be quickly removed or exchanged.

for small machines. For such equipment as pumps, fans, gear reducers, and the like, a common bedplate is usual as shown in Fig. 6. For many other machines some form of bracket or platform is arranged.

The essential requirements of a good foundation or support for a motor are, in brief, (*a*) provision for a firm and solid support for the machine so that it will not settle or otherwise move under the influence of its weight, and (*b*) provision of sufficient weight or rigidity to prevent excessive vibration of the machine if it should be unbalanced or acted upon by unsteady forces. Motors should not be directly attached to or supported by machines which vibrate or shake, as the motors will likely develop trouble under such conditions. Some sort of flexible drive should be used. Railway, mine and mill-type motors are better adapted than general-purpose motors to withstand such conditions.

Care should be exercised to have the motor shaft level; otherwise end-pounding may result. In special cases, where the motor must be mounted with the shaft on a slope, or where pitching may be encountered, ring-oiling bearings should be avoided and some type of ball or roller bearing should be used having suitable end-thrust features. The end-thrust of a driven machine must not be taken by a motor unless special provision is made.

Particular attention must be paid to the type of foundation used. When mounting motors upon a floor, it is advisable to elevate the motor sufficiently to keep it above dirt and moisture, with sufficient space for sweeping. From 6 to 12 in. above the floor is preferred. For belt or chain drives, the sliding base or rails supplied by the motor manufacturer may well be used. Where slide-rails are used care should be exercised to see that they are set to afford a plane surface for the motor to rest upon. Motor bases are usually heavy enough to retain their shape under stress, but they should not be bolted down in a manner to distort them. Slide-rails or bases may be most readily installed by providing a concrete foundation with anchor bolts, the base being aligned with wedges and grouted in. A clever bracket arrangement used on 250 motors by one manufacturer is shown in Fig. 5.

When a direct-connected or geared motor without base is separately mounted on a concrete foundation it should not be grouted in, as removing for exchange or repair is then difficult. Some sort of metal baseplate should be anchored and grouted on the concrete foundation and the motor should then be attached thereto. Fig. 2 shows a motor mounted on castings which are well adapted for this service. A few

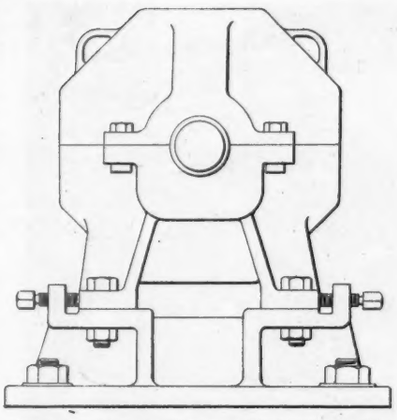
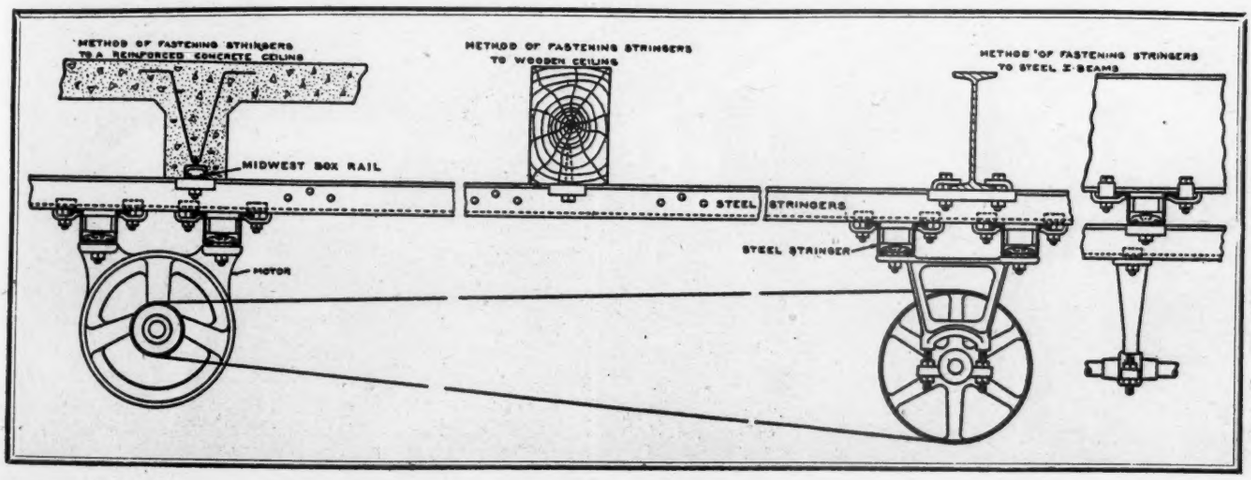


Fig. 3—A mounting that permits of horizontal adjustment of motor to facilitate aligning gears.

This mounting takes the form of a subbase on which there are adjusting screws, as shown, to align the motor. In a mill motor of the size shown, two adjusting screws are required on each side as well as two adjusting screws on each end, making a total of eight screws for the motor.

Fig. 4—Mounting motors on the ceiling by the use of special steel stringers.

Lineshafts are often supported by the special Midwest Steel & Supply Company's box rails, to which are attached steel stringers, as shown in the illustration. The box rail is cast into the concrete ceiling and fastened by the special reinforcement shown. Steel stringers are then clamped to the box rail and are readily adjustable to any desired position. Additional steel stringers are clamped at right angles to the first mentioned stringers and the motor is fastened to these as is shown in the illustration. This provides for adjustment of the motor in both directions so as to properly align the motor pulley with the driven pulley. A similar arrangement is used for mounting the lineshaft, as is shown at the right of the illustration.



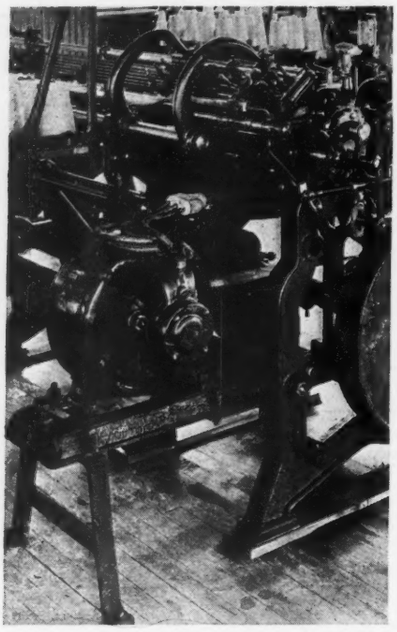


Fig. 5—Over 250 of this type of bracket arrangement for mounting motors are used at one factory.

The mounting consists of one floor bracket and two pieces of strap iron bent at an angle and attached to the frame of the machine, as is shown in the illustration.

such castings can be made to serve a variety of motors.

It is usually a simple matter, in providing a motor support, to so design it that a larger motor or one of different dimensions may be substituted.

This may be easily done by making the support a little larger than required and perhaps by inserting a changeable structural member, a plate, or a filler piece of some kind under the motor feet. The cost of such a provision is insignificant, a good mechanical job can be done, and the leeway allowed may prove invaluable if a change of motors becomes desirable for any reason. Such an installation is shown in Fig. 7.

In attaching a motor to a bedplate or a similar support, through bolts are preferable to capscrews or stud bolts as the motor may be more readily removed and breakage of a bolt is a less serious matter. When motors are mounted on timbers lagscrews are sometimes used to hold down the motor, or the sliding-base or rails. It is a good plan to fill the hole around the lag bolt with molten lead before tightening. Machines larger than 50-kw. capacity should not be mounted on wood timbers.

The use of dowels with direct-coupled or geared motors is common, but by no means universal, practice. This construction does not lend itself to ready interchange of motors. If heavy through bolts are used and these are well tightened, a motor will usually hold its position unless subjected to decided forces. Sometimes a base is provided with setscrews, as shown in Fig. 3, providing means for slight horizontal adjustments and preventing shifting.

Large motors of the pedestal type are usually provided with sole plates if the motor frame is not carried on

Figs. 6 and 7 — Direct-connected motors are usually mounted on a common bedplate.

Fig. 6 shows such a mounting used in steel mill service. The motor at the right is mounted on a bedplate and connected through a Jones speed reducer to a pipe conveyor. The speed reducer and motor are mounted on the bedplate which is part of the upper end of the conveyor. At the left is shown a motor directly connected to a hot saw. Here again the motor is mounted on a bedplate that is common to the saw and motor. Fig. 7 shows how a motor larger than was originally used, was mounted on a pipe charging crane. A steel plate about 1 in. thick and large enough to accommodate the larger motor was bolted to the original bedplate as shown in the illustration. The larger motor was then attached to the steel plate.

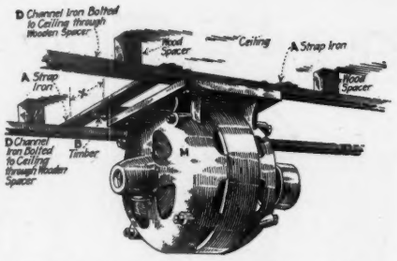


Fig. 8—Method of mounting motor to ceiling by using steel channels that are bolted to the ceiling through wood spacers.

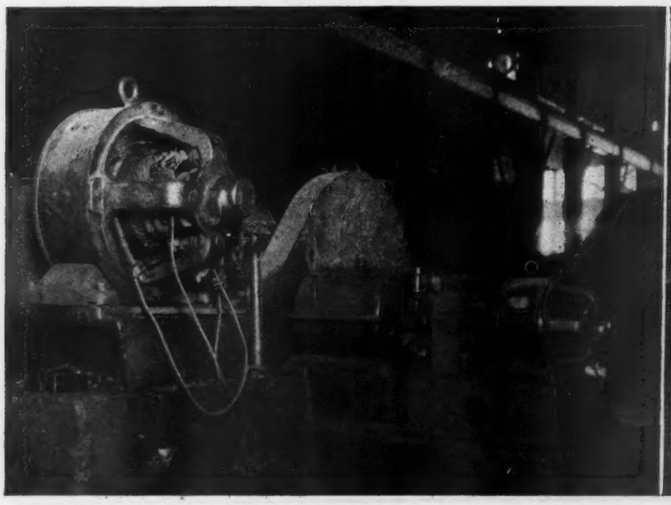
an extension of the base of the driven machine. These sole plates should be wedged into place and grouted in after the motor frame is aligned. It is good practice to provide about $\frac{1}{8}$ in. of shims between the motor feet and the sole plate, to allow for future adjustment. Sometimes the motor feet are provided with setscrews for lifting the motor for adjustment of shims. These setscrews should be used for adjustment purposes only and should be relieved during operation.

Particularly in the case of pedestal-type motors, and more commonly for alternating-current machines, it may be desirable to be able to slide the frame for access in making inspections or repairs. This need should be borne in mind when providing bedplates, sole plates, or bases.

The use of a hollow, boxlike base, particularly when made of light structural and plate members, is open to objection because slight vibration may give rise to objectionable noise through the sounding-board effect.

Motors of the general-purpose type may be readily arranged for side wall suspension by shifting the bearing brackets through 90 deg. They may then be bolted directly to the

(*Please turn to page 363*)



Electric Heating of Liquids and Compounds

together with an analysis of the problems involved and a description of some of the types of equipment available for this purpose

By LEE P. HYNES
President, Hynes & Cox Electric Corporation, Albany, N. Y.

HEAT in some form is vital to every industry, but particularly to those dealing with chemicals, liquids and compounds of all kinds. In heating such materials great care is frequently necessary from the standpoints of safety or quality of product, and the problems involved are usually so varied that each case needs careful analysis.

Heating problems of this nature may profitably be divided into three general classes, according to the temperatures required, and the advantages of various heating methods discussed. These classes by temperature ranges are: Low, up to 100 deg. C.; medium, from 100 deg. to 170 deg. C.; and high, 170 deg. to 500 deg. C. For the low-temperature class, steam may be utilized in conjunction with a water bath. In the medium-temperature class steam may be used at pressures corresponding to the required temperature, although the pressure rises to approximately 100 lb. per sq.in. at 170 deg. C. For the high-temperature class, fuel-fired furnaces which employ coal, coke, gas, or oil, may be used.

Electricity, however, is the only heating medium which can be used satisfactorily for all three classes of work. It would be incorrect to claim that it is always the proper means to select. That is a question which depends entirely upon several factors, economic as well as technical. Nevertheless, electricity possesses such flexibility and ease of control, that it can often be used to very great advantage for large and small jobs. The general use of electric motors for power purposes has eliminated high-pressure steam boilers from most plants, except where high-pressure steam is needed for heating in some process. If used intermittently, steam may be inconvenient and expensive, and often electricity could profitably be substituted.

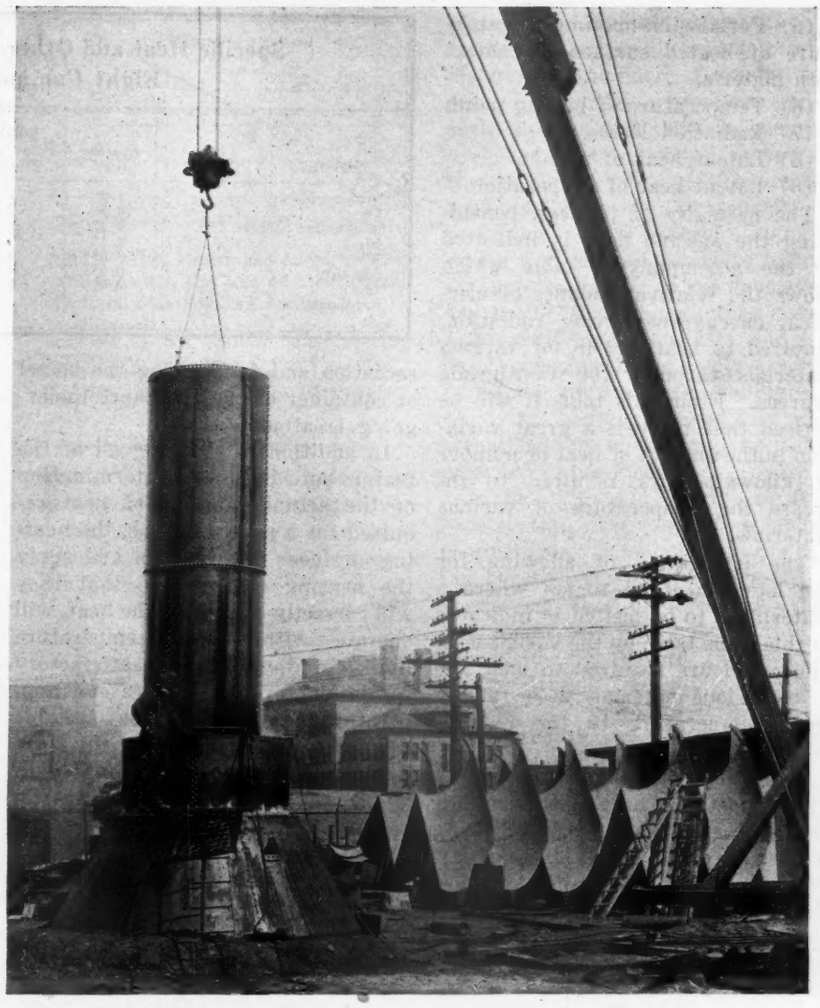


Fig. 1—This 7,000-gal. vertical pitch kettle is electrically heated.
This kettle is 40 ft. deep, the major portion of it being sunk underground to prevent heat losses. The pitch in it is stirred by means of air jets in the bottom of the kettle. Large sections of steel conduit are coated by dipping them in the molten pitch by means of the jib crane, as shown.

To apply electric heat successfully to any process requires careful design of the equipment and a thorough study of the process. Too often the practical operator who is used to heating by steam fails to appreciate the difference in principle between steam and electric heating. Steam is a constant-temperature medium (at constant pressure) and will give up its heat as rapidly as it can be condensed. Electric heating is exactly opposite in principle, being a constant-input method. This basic difference is clearly illustrated by the curves in the chart given in Fig. 3, which shows the decrease in rate of absorption of heat from the steam by the surface being heated as the temperature of the surface approaches the temperature of the steam. Electricity, on the other hand, generates a constant quantity of heat which must be disposed of and, therefore, the temperature of the heating element will rise until the difference in temperature between it and the surface being heated is sufficient to cause that constant quantity of heat to pass.

In designing any electric heating installation it is necessary to consider at least some of the following items:

(1) Weight of material to be heated per unit of time.
(1) Specific heat of material.
(3) Conductivity of material.
(4) Viscosity of material.

(5) Permissible maximum temperature of heated surface in contact with material.

(6) Temperature of boiling point.

(7) Radiation losses.

(8) Latent heat of fusion.

(9) Latent heat of evaporation.

The necessity of properly considering the specific heat is indicated by the accompanying table which shows the relative amounts of electrical energy, neglecting radiation, required to heat 100 lb. of various materials through 100 Centigrade degrees. From this table it will be noticed that there is a great variation in the amount of heat or number of kilowatt-hours required to increase the temperature of various materials.

The importance of allowing for the latent heat of fusion where a material is to be melted is indicated in this same table by the variation in kilowatt-hours required to melt 100 lb. of various materials, after raising their temperature to the melting point.

Hence it is seen that for melting a given substance, heat is required for raising the substance to the melting temperature, as shown in the first two columns of the table and also for converting the substance from the solid state to the liquid as given in the last two columns of the table. Similarly, heat is required for raising a liquid to the boiling point and for converting it from the liquid state to a gaseous form. In addition heat must be supplied to take care of radiation and for heating the vessel or container of the substance undergoing treatment.

Specific Heat and Other Physical Properties of Eight Common Materials

Material	Specific Heat	Kw.-hr. to Raise 100 Lb. 100 Deg. C.	Melting Point Deg. C.	Latent Heat of Fusion B.t.u. per Lb.	Kw.-Hr. to Melt 100 Lb.
Water—Ice	1.0	5.27	0	144.0	4.20
Oil	0.5	2.64	....	....	....
Aluminum	0.22	1.15	658.7	138.6	4.05
Steel	0.11	0.58	....	....	....
Tin	0.059	0.31	231.9	25.7	0.75
Mercury	0.033	0.17	....	....	....
Lead	0.029	0.15	327.0	10.0	0.29
Sulphur	....	....	115.0	16.9	0.49

In addition to studying all of the factors entering into a determination of the actual quantity of heat required for a particular job, the heating engineer must design and apply the heating elements so that they will correctly distribute the heat, will operate within safe temperature limits, and will have satisfactory insulation for the voltages and temperatures involved. Also suitable regulation for controlling the temperature must be provided.

For small work, portable or stationary heating pots such as are shown in Fig. 2, are useful. These pots can be obtained in several different sizes ranging from 2 to 3 qt. to several gallons' capacity. The 5-gal. size is commonly used for boiling pinions in repair shops before pressing them on motor shafts. These pots are also used for melting alloys such as solder, babbitt, and the like as well as for heating water, oils, and compounds. The cable and control for the pots are detachable for convenience when pouring bearings, splicing cables on poles and the like.

For heating large volumes of liquids of considerable viscosity, or those which may be carbonized or damaged by overheating, it is necessary to provide a constant mechanical circulation. This is sometimes accomplished by means of mechanical stirring devices, sometimes by the introduction of air jets, and sometimes by circulating the material with a pump. For heating oil the last method is usually best. At the lower right of Fig. 2 is an electrically-heated oil tank designed for spraying hot oil on ball bearings during the course of their manufacture. From the spray all surplus oil is drained back to a reservoir and pumped into the heating tank, thus keeping up a constant circulation. The temperature of the oil in the main tank is controlled automatically.

A much larger type of circulating

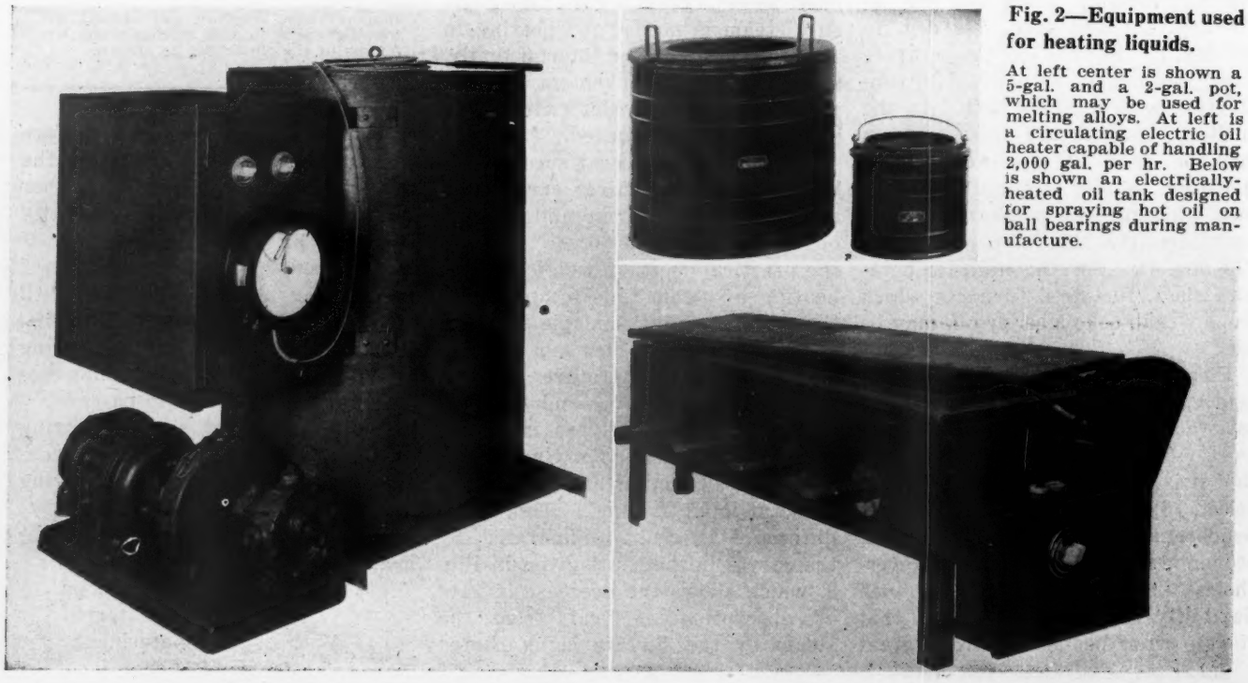


Fig. 2—Equipment used for heating liquids.

At left center is shown a 5-gal. and a 2-gal. pot, which may be used for melting alloys. At left is a circulating electric oil heater capable of handling 2,000 gal. per hr. Below is shown an electrically-heated oil tank designed for spraying hot oil on ball bearings during manufacture.

electric oil heater is shown at left, Fig. 2. It is made in standard sizes to handle as much as 2,000 gal. of oil per hour. It consists of an insulated tank lined with a helical coil of steel pipe through which oil is circulated by an electrically-driven rotary pump. Inside of the pipe coil is a cylindrical electric heater which heats the oil as it passes rapidly through the coil. By properly proportioning the watts per unit of heated coil surface for various velocities of oil circulation, almost any results that may be desired can be obtained.

These ratings will vary for different grades and velocities of oils, but when the proper rating is used there should be no carbonizing of the oil and no deposit of sediment on the interior of the coils, as the scouring action of the moving liquid will prevent this. An equipment of this kind is useful for the uniform heating of large vats of oil for drawing the temper of steel tools and springs. The thorough circulation, combined with automatic control, gives ideal temperature regulation. This method is also useful for preheating heavy fuel oil for large oil furnaces, and also for heating oil for recleaning by centrifugal separators.

A large electrically-heated vertical pitch kettle which holds 7,000 gal. of pitch is shown in Fig. 1. This kettle is 40 ft. deep and 7 ft. 6 in. in diameter, being sunk in the ground and insulated to prevent heat losses to the earth. It is rated at 198 kw., 550 volts, three phase. The pitch is kept constantly stirred by admitting air at a pressure of 100 lb. per sq.in. through jets in the bottom of the kettle.

When dipping large sections of steel conduit, the control is set to maintain the pitch at a uniform temperature of 300 deg. to 400 deg. F., according to the requirements of the particular work in hand.

Many more examples might be cited to show the unique adaptability of electricity for heating large and small tanks, kettles and industrial processes using various liquids and compounds, but in every case success depends upon a correct analysis of the thermal problems involved and their proper solution.

When properly applied, electricity frequently has many advantages for this class of work over any other heating medium. This is especially true for temperatures below the temperature of steam at atmospheric pressure and for high temperatures, above those available with ordinary saturated steam. Every case, however, is an individual problem of a most interesting nature.

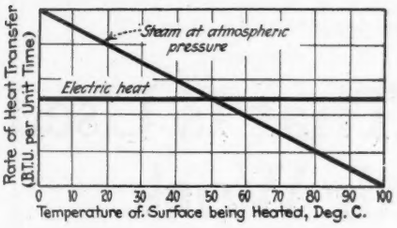

Steam at atmospheric pressure
Electric heat
Rate of Heat Transfer (B.T.U. per Unit Time)
0 10 20 30 40 50 60 70 80 90 100
Temperature of Surface being Heated, Deg. C.

Fig. 3—This shows the basic difference between the use of steam and electricity as heating mediums.

The absorption of heat from steam falls off as the surface being heated approaches that of the steam. Electricity generates a constant quantity of heat; hence this form of heating will cause absorption of a constant quantity of heat.

Installation of Motors

(Continued from page 360)

wall, to a beam, as shown at *A* on page 358, bolted directly to the side of the driven machine, as shown at *H*, or bolted to a platform or bracket that is fastened to the wall, as shown at *B*, on page 358.

Fastening the motor directly to the wall is the cheaper form of construction and usually provides the stronger support; however, this form of installation is more difficult to align and level and the motor is more inaccessible, which renders inspection and maintenance difficult. For this reason, the bracket or platform support is usually preferred for wall mounting.

A good bracket mounting is shown at *A* on page 358. For larger motors it would be advisable to use angle braces to insure sufficient rigidity. In the case of large motors it is desirable that the platform be made large enough to allow a man to get around to all sides of the motor so as to render inspection easy.

Platforms or mounting brackets are often attached to building columns instead of to walls. In such cases, however, care should be taken that the bending moment or overhang of the motor and platform on the column is not enough to cause trouble. The motor should be placed as close to the column as possible, for the closer it is to the column, the less will be the stress on the latter.

Not infrequently motors are attached to the ceiling. This practice is open to the objection that the motors are not so accessible as when mounted on the floor. However, floor space is often at a premium and in such cases motors must be mounted overhead. In mounting motors on the ceiling the principal feature that requires attention is security of fastening. In general, supports which are secured by bolts passing through the ceiling to the floor above are better than many other forms. Lagscrews, expansion bolts, and similar fastenings should not be used for fastening motors to the ceiling. In buildings having a wood-joist construction the motor can be easily attached to the joists.

In buildings of concrete or steel construction, the use of a double channel iron frame bolted to the ceiling through spacers is suggested as permitting ease of installation and alignment. Such a construction is shown in Fig. 8. In the case of motors driving lineshafts, especially designed, pressed-steel stringers are often used to support the lineshaft hangers and use may be made of them, as shown in Fig. 4, to mount the motor. In this method, box beams are imbedded at intervals in the ceiling, to which steel cross-stringers are clamped. So as to provide adjustment in two directions on a horizontal plane, two stringers are fastened at right angles to the first mentioned stringers and the motor is clamped thereto, as illustrated in Fig. 4.

When there is sufficient space available, it is often preferable to mount a motor in an pright position on a platform suspended from the ceiling. If the distance between the motor and the ceiling is sufficient to accommodate a man, the motor can be easily cleaned and maintained while in place. However, with this form of mounting it is more difficult to prevent movement and vibration than when the motor is attached directly to the ceiling. For this reason the mounting should be rigidly constructed with sufficient cross-bracing. A clever ceiling mounting for a small motor is shown at *C* in the illustrations on page 358.

This article is the first of a series dealing with the mechanical features of motor installation. Succeeding articles which will appear in early issues, will deal with the application of couplings, clutches, belts, chains, gears, speed reducers, and variable-speed transmissions as used to connect the motor to the driven machine.

Some practical information on

Copper Wire That Is Used in Motor Repair Work

together with handy wire tables and an explanation of how they can be employed to save time on every-day and special rewinding jobs

By A. C. ROE
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and
D. H. BRAYMER,
Consulting Editor, Industrial Engineer

THIS IS the first of a series of articles that will deal with the various materials used in motor and generator rewinding and repair jobs. Details will be given of the materials themselves and how they can best be used on a particular machine so as to save time for the repairman and help him to make sure that the results he hopes to get will be realized with the least possible guess-work. This article takes up the most common of all materials used: namely, copper wire, in the shapes and sizes most frequently employed in motor windings. The next article will deal with wire insulation.

THE vitals of a motor or generator are its windings. In spite of extreme care and expert workmanship on a rewinding job, if poor materials are used, or those which are not suited to the service under which the machine must operate, troubles are bound to show up and the repair will be unsatisfactory and expensive to all concerned. But when suitable materials are used under the same circumstances, a rewound motor will give all the service that was expected of it when new.

The base of all windings is copper wire in round, square, ribbon or strap form, and this wire is insulated in various ways by the wire manufacturer. In this article the wire itself will be discussed, and the insulating coverings commonly used will be considered in another article, to appear in an early issue.

The electrical conductivity of copper is second only to that of silver; this feature, combined with good mechanical strength, is the reason for its wide use in electrical windings. For round, strap and ribbon wire used in windings, the conductivity should be not less than 98 per cent. Conductivity of 100 per cent is based on copper having a resistance of 0.1530 ohm per meter gram at 20 deg. C. (68 deg. F.) or 8.306 ohms per square mil foot at 25 deg. C. (77 deg. F.). For calculating weights, etc., the specific gravity of the copper should be taken as 8.89 at 20 deg. C.

The maximum tensile strength in pounds per square inch on tension test should be as follows for round wire and ribbon:

0.003—0.020 in. thick, 40,000 lb. Elongation 20%
0.020—0.050 in. thick, 38,000 lb. Elongation 35%
Over 0.050 in. thick, 37,000 lb. Elongation 30%

The elongation in 10 in. should not be *less* than the percentage given above. These data are for soft-drawn, thoroughly annealed copper wire, ribbon or strap, free from scale, clean and free from cracks, laminations or brittleness. A good grade of wire should be free from joints and all necessary joints should be identical in softness, dimensions, etc., with the main body of the wire. The strength of any joint should be at least 95 per cent of the strength of the clear wire.

A good grade of soft-drawn, square or ribbon copper wire should meet the bending test given in Table I. This test determines the minimum diameter of pin that the wire can be bent around 180 deg. on edge (edgewise) without fracturing or cracking the edges. The dimensions given in Table I are for bare copper and the body of the table gives the diameter of the pin.

A few practical tests can be made which will enable one to judge the grade of wire being supplied. An experienced coil winder can usually tell whether the wire or strap is too hard or springy by the feel of it while forming. It is hard to show this hardness or springiness in figures, but a tension test for per cent of elongation will put it in its proper class.

Soft-drawn, annealed copper becomes hard when worked, that is bent on edge around small pins or bent back and forth a number of times at one spot, but by annealing at about 300 deg. C. (572 deg. F.) it regains its original state, approximately. Copper may be heated to a cherry or dull red and thrown into cold water and cooled quickly, or it can be allowed to cool in the air and it will be equally soft. When the copper is heated to a cherry or dull red heat, it unites with the oxygen in the air and forms one or both of two oxides, which are known as black copper scale and red copper scale. The black scale is infusible, but can be removed by quenching in cold water after annealing. The main points to watch are not to get the copper too hot and to keep the water cold. Most strap copper bent on edge can be annealed around the bends as

Table I—Diameters of Pins to Use in Bending Test for Ribbon and Strap Copper Wire

Bare Wire, Thickness in Inches	Width of Bare Wire in Inches						
	0.000 to 0.160	160 to 180	180 to 260	260 to 325	325 to 365	365 to 410	410 to 500
	Diameter of Pin to Use in Inches						
0.025 to 0.030	1/4	3/8	1/2	5/8	5/8	3/4	3/4
0.030 to 0.040	1/4	1/4	3/8	1/2	5/8	5/8	5/8
0.040 to 0.050	1/8	1/4	1/4	3/8	1/2	1/2	5/8
0.050 to 0.062	1/8	1/4	1/4	1/4	3/8	1/2	1/2
0.062 to 0.080	1/8	1/8	1/4	1/4	3/8	3/8	1/2
0.080 up	1/8	1/8	1/4	1/4	1/4	3/8	3/8

described and will not need to be cleaned in acid. In annealing copper, the less air present the smaller will be the amount of scale formed.

Copper does not tarnish in dry air, but in damp air in the presence of carbon dioxide it becomes coated with verdigris or copper carbonate and the outer surface of the copper turns green. This is quite often seen on wire removed from old machines that have been in service for a number of years. Where untreated material such as cotton, red rope paper, etc., is in close contact with the copper, the cotton or other untreated material absorbs moisture, which in turn forms the verdigris. There does not seem to be any harm resulting from the formation of verdigris on copper at normal winding voltages, but proper baking and dipping will reduce, and in some cases prevent, the formation of this verdigris. Soldering acids (zinc chloride solution) and some soldering pastes also form this verdigris on the copper with this difference: the corrosion penetrates and attacks the insulating material.

When copper wire is to be rubber covered, the wire is first tinned, as the sulphur in the rubber attacks the copper, forming copper sulphide. Tin is not affected by sulphur.

Wire that is used for windings of electrical machines can be classified according to diameter, width, thickness, etc. The B & S wire gage is usually used in the United States. A complete history of the wire tables, sizes, etc., will be found in Circular No. 31 of the Bureau of Standards, Washington, D. C. (Price 10 cents.)

Table II gives the standard American wire gage (B & S) data for bare round copper wire. This table is taken from the above circular. The cross-sectional area of all wire in this series of articles will be given both in circ.mils and square inches for round and square wire, and in square inches only for ribbon and strap forms.

In writing up coil specifications covering round wire the decimal size of the wire will be found more convenient than the B & S gage number. For example: 50 lb. of 0.0641 round copper magnet wire.

Wire Table Short Cuts.—Since the American (B & S) wire gage is formed by geometrical progression, there are a number of easily remembered ratios that will enable one to compute any wire size ratings without the necessity of referring to a

Table II—Resistance and Dimensions of Standard, Annealed, Round B & S Gage Copper*

Gauge No.	Diameter in Mils.	Cross Section		Pounds per 1000 Feet	Feet per Pound	Resistance of Pure Copper at 25° C. (=77° F.)			
		Circular Mils.	Square Inches			Ohms per 1000 Feet	Feet per Ohm	Pounds per Ohm	Ohms per Pound
0000	460.0	211600.	.1662	640.5	1.561	.04998	20010.	12810.	.00007805
000	409.6	167800.	.1318	507.9	1.968	.06303	15870.	8057.	.0001241
00	364.8	133100.	.1045	402.8	2.482	.07947	12580.	5067.	.0001974
0	324.9	105500.	.08289	319.5	3.130	.1002	9979.	3187.	.0003138
1	289.3	83690.	.06573	253.3	3.947	.1264	7913.	2004.	.0004990
2	257.6	66370.	.05213	200.9	4.977	.1594	6276.	1260.	.0007934
3	229.4	52640.	.04134	159.3	6.276	.2009	4977.	792.7	.001262
4	204.3	41740.	.03278	126.4	7.914	.2534	3947.	498.6	.002006
5	181.9	33100.	.02600	100.2	9.980	.3195	3130.	313.5	.003189
6	162.0	26250.	.02062	79.46	12.58	.4029	2482.	197.2	.005071
7	144.3	20820.	.01635	63.02	15.87	.5080	1968.	124.0	.008064
8	128.5	16510.	.01297	49.98	20.01	.6406	1561.	77.99	.01282
9	114.4	13090.	.01028	39.63	25.23	.8078	1238.	49.05	.02039
10	101.9	10380.	.008155	31.43	31.82	1.019	981.8	30.85	.03242
11	90.74	8234.	.006467	24.92	40.12	1.284	778.5	19.40	.05155
12	80.81	6530.	.005129	19.77	50.59	1.620	617.4	12.20	.08196
13	71.96	5178.	.004067	15.68	63.80	2.042	489.6	7.673	.1303
14	64.08	4107.	.003225	12.43	80.44	2.576	388.3	4.826	.2072
15	57.07	3257.	.002558	9.858	101.4	3.248	307.9	3.035	.3295
16	50.82	2583.	.002028	7.818	127.9	4.095	244.2	1.909	.5239
17	45.26	2048.	.001609	6.200	161.3	5.164	193.7	1.200	.8330
18	40.30	1624.	.001276	4.917	203.4	6.512	153.6	.7549	1.325
19	35.89	1288.	.001012	3.899	256.5	8.210	121.8	.4748	2.106
20	31.96	1022.	.0008023	3.092	323.4	10.35	96.59	.2986	3.349
21	28.46	810.1	.0006363	2.452	407.8	13.06	76.60	.1878	5.325
22	25.35	642.4	.0005046	1.945	514.2	16.46	60.74	.1181	8.467
23	22.57	509.5	.0004002	1.542	648.4	20.76	48.17	.07427	13.46
24	20.10	404.0	.0003173	1.223	817.7	26.18	38.20	.04671	21.41
25	17.90	320.4	.0002517	.9699	1031.	33.01	30.30	.02938	34.04
26	15.94	254.1	.0001996	.7692	1300.	41.62	24.02	.01847	54.13
27	14.20	201.5	.0001583	.6100	1639.	52.48	19.05	.01162	86.07
28	12.64	159.8	.0001255	.4837	2067.	66.18	15.11	.007307	136.8
29	11.26	126.7	.00009953	.3836	2607.	83.46	11.98	.004595	217.6
30	10.03	100.5	.00007894	.3042	3287.	105.2	9.503	.002890	346.0
31	8.928	79.70	.00006260	.2413	4145.	132.7	7.536	.001818	550.2
32	7.950	63.21	.00004964	.1913	5227.	167.3	5.976	.001143	874.8
33	7.080	50.13	.00003937	.1517	6591.	211.0	4.739	.0007189	1391.
34	6.305	39.75	.00003122	.1203	8310.	266.1	3.759	.0004521	2212.
35	5.615	31.52	.00002476	.09542	10480.	335.5	2.981	.0002843	3517.
36	5.000	25.00	.00001964	.07568	13210.	423.0	2.364	.0001788	5592.
37	4.453	19.83	.00001557	.06001	16660.	533.5	1.874	.0001125	8892.
38	3.965	15.72	.00001235	.04759	21010.	672.7	1.487	.00007074	14140.
39	3.531	12.47	.000009793	.03774	26500.	848.2	1.179	.00004448	22480.
40	3.145	9.888	.000007766	.02993	33410.	1070.	.9349	.00002798	35740.

*From Bureau of Standards Circular No. 31.

NOTE: The values given in the table are only for annealed copper of the standard resistivity. The user of the table must apply the proper correction for copper of any other resistivity. Hard-drawn copper may be taken as about 2.7 per cent higher resistivity than annealed copper.

Table III—Equivalent Cross-Sections of Bare, Solid and Stranded B & S Gage Wires*

Size	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	0	Size
0000	2105	1670	1324	1050	833	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	2	0000
000	1670	1324	1050	833	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	000
00	1324	1050	833	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	. .	00
0	1050	833	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	1	0
1	833	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1
2	661	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	. .	2
3	524	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	3
4	415	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	4
5	329	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	5
6	261	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	6
7	207	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	7
8	164	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	8
9	130	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	9
10	103	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	10
11	82	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	11
12	65	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	12
13	52	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	13
14	41	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	14
15	32	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	15
16	26	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	16
17	20	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	17
18	16	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	18
19	13	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	19
20	10	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	20
21	8	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	21
22	6	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	22
23	5	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	23
24	4	. .	. .	2	. .	. .	1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	24
Size	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	0	Size

*Rome Wire Company.

NOTE: The upper and lower lines of figures indicate the sizes. The body of the table gives the number of wires equivalent in cross-section to the sizes in the right and left margins.

wire table. These figures will be correct to within 2 per cent.

The resistance, mass, and cross-section of round wire vary with the square of the diameter. The next size larger or smaller than any given size is $1.26 \times X$ or $X \div 1.26$, where X is the circ.mil area of the known size. For example: Take a No. 10 (0.1019 in.) wire which has an area of 10,380 circ. mils. Then $1.26 \times 10{,}380 = 13{,}084$ circ. mils, which according to Table II is a No. 9 wire. Also, $10{,}380 \div 1.26 = 8{,}238$ circ. mils, which is No. 11 wire.

For every ten gage sizes the resistance, pounds per 1,000 ft., and cross-section are divided by 10 or multiplied by 10. For example: A No. 20 wire is $\frac{1}{10}$ the area of a No. 10, and a No. 20 has ten times the resistance of a No. 10, etc.

Every third larger gage number is twice the area, and every third smaller gage number is one-half the area of any given wire size. For example: A No. 10 wire has an area of 10,380 circ. mils; then 10 plus 3 or No. 13 wire has an area of 5,178 circ. mils. When one line of the wire table is memorized, the data for any other gage size can be computed for rough work by these approximate rules.

The cross-sectional area of round, square, and ribbon wire is usually given in circular mils. The cross-section in circular mils of a single wire is the square of its diameter in mils. The mils equal the diameter in inches times 1,000. If D equals the diameter in mils, circ. mils equal $D \times D$. Thus, the diameter of a No. 10 wire is 0.1019 in.; then D in mils equals $0.1019 \times 1{,}000 = 101.9$, and the circ. mils equal 101.9×101.9 or 10,836.

In computing the cross-sectional area of square or ribbon wire and copper strap, the copper loss in the rounding of the corners must be taken into consideration. The cross-section of copper strap is generally given in square inches. Then to compare a strap with a ribbon or round wire, it is necessary to convert the square inches to circular mils. Circ. mils equals sq.in. $\div$ 0.000,000,7854. A quicker method is to divide the sq.in. by 1,000,000 and then divide the result by 0.7854.

Table III is a very handy one for the repairman. This table gives the number of B & S gage wires equivalent to one large wire. For example, the first and last vertical columns give the B & S gage size from 0000 to 24. The top and bottom horizontal lines give the B & S size from 0 to 30. By consulting the horizontal line for No. 8 wire, we find that one No. 8 is equal to 164 No. 30 wires, 130 No. 29 wires, etc.

This is a handy table when a rush job comes up and the required wire size is not in stock. It shows all the

Table IV—Outside Diameter of Round Copper Wires with Different Types of Insulating Coverings

B & S Gauge Size	Cross Section		Diameter of Wire Over Insulation in Inches										
	Circular Mils	Square Inches	Bare Diameter in Inches	Enamel Covered (EN)	Single Cotton Covered (S-C-C)	Double Cotton Covered (D-C-C)	Single Cotton and Enamel (S-C-EN)	Double Cotton and Enamel (D-C-C-EN)	Triple Cotton Covered (T-C-C)	Single Silk Covered (S-S-C)	Double Silk Covered (D-S-C)	Single Silk and Enamel (S-S-EN)	Double Silk and Enamel (D-S-EN)
0000	211,600	0.1662	0.4600	.....	0.4690	0.4780	.....	.....	0.4870	.....	.....	.....	.....
000	167,800	0.1318	0.4096	.....	0.4186	0.4276	.....	.....	0.4366	.....	.....	.....	.....
00	133,100	0.1045	0.3648	.....	0.3738	0.3828	.....	.....	0.3918	.....	.....	.....	.....
0	105,500	0.08289	0.3249	.....	0.3319	0.3429	.....	.....	0.3519	.....	.....	.....	.....
1	83,690	0.06573	0.2893	.....	0.2983	0.3073	.....	.....	0.3163	.....	.....	.....	.....
2	66,370	0.05213	0.2576	.....	0.2666	0.2756	.....	.....	0.2846	.....	.....	.....	.....
3	52,640	0.04134	0.2294	.....	0.2384	0.2474	.....	.....	0.2564	.....	.....	.....	.....
4	41,740	0.03278	0.2043	.....	0.2133	0.2223	.....	.....	0.2313	.....	.....	.....	.....
5	33,100	0.02600	0.1819	.....	0.1909	0.1999	.....	.....	0.2089	.....	.....	.....	.....
6	26,250	0.02062	0.1620	.....	0.1700	0.1780	.....	.....	0.1860	.....	.....	.....	.....
7	20,820	0.01635	0.1443	.....	0.1523	0.1603	.....	.....	0.1683	.....	.....	.....	.....
8	16,510	0.01297	0.1285	0.1300	0.1355	0.1425	0.1355	0.1410	0.1495	.....	.....	.....	.....
9	13,090	0.01028	0.1144	0.1164	0.1204	0.1264	0.1220	0.1274	0.1324	.....	.....	.....	.....
10	10,380	0.00816	0.1019	0.1038	0.1069	0.1119	0.1093	0.1148	0.1169	.....	.....	.....	.....
11	8,234	0.00647	0.0907	0.0927	0.0957	0.1007	0.0882	0.1037	0.1057	.....	.....	.....	.....
12	6,530	0.00513	0.0808	0.0828	0.0858	0.0908	0.0883	0.0938	0.0958	.....	.....	.....	.....
13	5,178	0.00407	0.0720	0.0740	0.0770	0.0820	0.0795	0.0850	0.0860	.....	.....	.....	.....
14	4,107	0.00323	0.0641	0.0660	0.0691	0.0731	0.0715	0.0770	0.0781	.....	.....	.....	.....
15	3,257	0.00256	0.0571	0.0585	0.0621	0.0661	0.0640	0.0695	0.0711	0.0591	0.0610	0.0607	0.0627
16	2.583	0.00203	0.0508	0.0523	0.0558	0.0598	0.0573	0.0623	0.0648	0.0528	0.0547	0.0543	0.0563
17	2,048	0.00161	0.0453	0.0467	0.0502	0.0542	0.0517	0.0563	0.0592	0.0472	0.0491	0.0486	0.0506
18	1,624	0.00128	0.0403	0.0418	0.0453	0.0493	0.0468	0.0518	0.0543	0.0423	0.0442	0.0437	0.0457
19	1,288	0.00101	0.0359	0.0374	0.0409	0.0449	0.0424	0.0474	0.04 9	0.0379	0.0398	0.0393	0.0413
20	1,022	0.000802	0.03196	0.0334	0.0370	0.0410	0.0379	0.0424	0.0460	0.0340	0.0359	0.0352	0.0371
21	810.1	0.000636	0.02846	0.0294	0.0335	0.0375	0.0339	0.0384	0.0425	0.0305	0.0324	0.0316	0.0335
22	642.4	0.000505	0.02535	0.0263	0.0303	0.0343	0.0308	0.0353	0.0393	0.0273	0.0292	0.0285	0.0304
23	509.5	0.000400	0.02257	0.0236	0.0276	0.0316	0.0 81	0.0326	0.0366	0.0246	0.0 65	0.0256	0.0 75
24	404.0	0.000317	0.02010	0.0210	0.0251	0.0291	0.0255	0.0300	0.0.41	0.0221	0.0240	0.0232	0.0251
25	320.4	0.000252	0.01790	0.0187	0.0229	0.0269	0.0232	0.0277	0.0319	0.0199	0.0218	0.0209	0.0228
26	254.1	0.0001996	0.01594	0.0167	0.0209	0.0249	0.0207	0.0247	0.0299	0.0179	0.0198	0.0189	0.0208
27	201.5	0.0001583	0.01420	0.0149	0.0192	0.0232	0.0189	0.0229	0.0282	0.0162	0.0180	0.0171	0.0189
28	159.8	0.0001255	0.01264	0.0133	0.0176	0.0216	0.0173	0.0213	0.0266	0.0146	0.0164	0.0155	0.0173
29	126.7	0.0000995	0.01126	0.0120	0.0163	0.0203	0.0160	0.0200	0.0253	0.0133	0.0149	0.0140	0.0156
30	100.5	0.00007894	0.01003	0.0107	0.01502	0.01802	0.0147	0.0187	0.02402	0.01202	0.01362	0.01285	0.01445
31	79.70	0.00006260	0.008928	0.0094	0.01392	0.01792	0.0134	0.0174	0.02292	0.01092	0.01252	0.01167	0.01327
32	63.21	0.00004964	0.007950	0.0084	0.01295	0.01695	0.0124	0.0164	0.02195	0.00995	0.01155	0.01065	0.01225
33	50.13	0.00003937	0.007080	0.0075	0.01208	0.01608	0.0115	0.0155	0.02108	0.00908	0.01068	0.00973	0.01133
34	39.75	0.00003122	0.006305	0.0068	0.01130	0.01530	0.0108	0.0148	0.02030	0.00830	0.00990	0.00890	0.01050
35	31.52	0.00002476	0.005615	0.0060	0.01061	0.01461	0.0100	0.0140	0.01961	0.00761	0.00921	0.00816	0.00976
36	25.00	0.00001964	0.005000	0.0054	0.01000	0.01400	0.0094	0.0134	0.01900	0.00700	0.00860	0.00750	0.00910
37	19.83	0.00001557	0.004453	0.0048	0.00945	0.01345	0.0088	0.0128	0.01845	0.00645	0.00805	0.00694	0.00854
38	15.72	0.00001235	0.003965	0.0043	0.00896	0.01296	0.0083	0.0123	0.01786	0.00596	0.00756	0.00639	0.00799
39	12.47	0.00000979	0.003531	0.0038	0.00853	0.01253	0.00836	0.01296	0.01753	0.00553	0.00713	0.00596	0.00756
40	9.888	0.00000777	0.003145	0.0033	0.00814	0.01214	0.00857	0.01257	0.01714	0.00514	0.00674	0.00557	0.00717

possible combinations that will give the same cross-sectional area of copper. Of course, the space factor (room in the slot) and the mechanical arrangement of the wires in the slot will be the deciding factors on the number of smaller wires that can be used. On the other hand, assume that an old type machine is being considered, having partly closed slots with large conductors and a shove-through type of winding of low voltage. The table will indicate the number of wires in hand of the size that will go through the slot opening, to permit the use of a mush coil, two-layer winding.

For example, assume that the old winding used a No. 9 wire and that the slot opening would allow a No. 16 wire to pass. We then find No. 16 in the top horizontal line and look down this column to the No. 9 line where we find the figure 5 which means that five No. 16 wires are equal to one No. 9. In the above example the five No. 16 bare wires will have the same copper cross-sectional area as the one No. 9 wire, but the room required in the slot for the five wires will be greater due to there being more cotton insulating material that must be considered.

Copper wire, round, square, ribbon or strap, must be insulated before being used in the construction of electrical windings. For round wires, this insulation may consist of coating the wire with enamel, or wrapping it with one, two or three layers of cotton or silk, or using an asbestos covering, or some combination of the above. The following are the various insulations applied to wire and the standard abbreviations used to designate each covering:

(1) Enamel covered wire.....En.
(2) Single cotton covered.....S.C.C.
(3) Double cotton covered.....D.C.C.
(4) Triple cotton covered.....T.C.C.
(5) Single silk covered.....S.S.C.
(6) Double silk covered.....D.S.C.
(7) Single cotton and enamel covered .....S.C.&En.
(8) Double cotton and enamel covered .....D.C.&En.
(9) Triple cotton and enamel covered .....T.C.&En.
(10) Single silk and enamel covered .....S.S.&En.
(11 Double silk and enamel covered .....D.S.&En.
(12) Asbestos covered. There are three grades of asbestos coverings; these will be explained later under the proper heading.
(13) Asbestos covering with one or two reinforcing coverings of cotton.

Table IV gives the over-all diameters of the B & S gage round wires when insulated with the coverings above listed as 1 to 11.

Table V—Dimensions, Weight and Resistance of Round, Enamel-Covered Magnet Wire

B. & S. Gage	Diameter Bare Wire in Inches	Feet per Pound	Pounds per 1,000 Feet	Ohms per Pound	Pounds per Ohm
8	0.1280	19.9	50.2	0.0125	80.0
9	0.1144	25.1	39.8	0.0198	50.5
10	0.1018	31.6	31.6	0.0315	31.7
11	0.0907	39.8	25.1	0.0500	20.0
12	0.0808	50.2	19.9	0.0796	12.6
13	0.0719	63.2	15.8	0.126	7.94
14	0.0641	79.6	12.6	0.201	4.97
15	0.0571	100	10.0	0.318	3.14
16	0.0508	125	7.94	0.505	1.98
17	0.0453	160	6.25	0.809	1.24
18	0.0403	202	4.95	1.29	0.775
19	0.0359	254	3.94	2.04	0.490
20	0.0320	319	3.14	3.24	0.319
21	0.0285	402	2.49	5.14	0.195
22	0.0253	506	1.98	8.16	0.123
23	0.0226	638	1.57	13.0	0.0770
24	0.0201	804	1.24	20.6	0.0485
25	0.0179	1,010	0.990	32.6	0.0307
26	0.0159	1,280	0.782	52.2	0.0192
27	0.0142	1,610	0.621	82.7	0.0121
28	0.0126	2,030	0.492	132	0.00758
29	0.0113	2,560	0.391	209	0.00478
30	0.0100	3.220	0.311	332	0.00301
31	0.0089	4,050	0.247	527	0.00190
32	0.0079	5,100	0.196	835	0.00120
33	0.0071	6,420	0.156	1,330	0.00075
34	0.0063	8,080	0.124	2,100	0.00048
35	0.0056	10,200	0.098	3,350	0.00030
36	0.0050	12,800	0.0782	5,300	0.00019
37	0.0044	16,100	0.0621	8,410	0.00012
38	0.0040	20,300	0.0492	13,400	0.000075
39	0.0035	25,500	0.0392	21,200	0.000047
40	0.0031	32,100	0.0312	33,600	0.000030

Enamel Covered Magnet Wire.—This wire is mostly used in small magnet and field coils and in winding small armatures such as are used in vacuum cleaners, small drills, etc., and is also used to some extent for small shunt field coils.

Bare copper wire should have the characteristics already explained and the enamel covering should have the following good features:

The enamel should adhere strongly to the wire and should not crack or split when subjected to the following test: Bake a sample at 100 to 110 deg. C. for at least 24 hr. and then bend it around a mandrel having a diameter of 1½ times the diameter of the wire for 0.0179-in. and smaller wire, or three times the diameter for 0.02-in. to 0.04-in., and four times the diameter for wire 0.04 in. and above. Under this test the enamel should not crack or peel and when subjected to an elongation test, a piece 10 in. long should elongate at least 25 per cent before cracking or peeling. This covering should not soften when subjected to baking at a temperature of 100-115 deg. C. for a period of at least 5 hr. A slight stickiness is an indication of softening of the enamel coating.

The enamel covering on the wire is generally tested by the wire manufacturers for bare or weak spots by passing the wire through a mercury bath at the rate of 600 ft. per minute; the voltage between the mercury and copper ranges between 25 and 75 volts direct current, according to the diameter of the wire. The number of faults per 100 ft. is used as the base upon which the wire is passed.

Other electrical tests can be made as follows: Wind at least ten turns around a metal mandrel ⅝ in. in diameter, the surface of which is smooth, that is free from burrs, lumps, etc.; then test between the wire and mandrel with direct current. The wire should stand at least 500 volts for 1 min., or the voltage can be increased until breakdown occurs. This test will indicate what one thickness of covering will stand.

To test between layers, wind two layers of the wire, one on top of the other, on a smooth mandrel approximately ¼ in. in diameter. Each layer should be at least 1 in. long. Then apply direct current voltage between layers. The enamel should

stand at least 500 to 1,000 volts before breakdown occurs.

The above tests will indicate the quality of the wire, but will not guarantee that the wire will stand up under abuse. For example, in winding small field coils, if the tension is applied to the rim of the reel or spool on which the wire is wound, care must be taken that the tension is not too great, as in this case the wire will be imbedded in the layers on the reel, causing rubbing and peeling of the enamel. Also, if a heavy tension is used and the winding machine is started with a jerk, the snap imparted to the wire will tend to crack the enamel. These points are mentioned because when trouble is experienced with coils wound with enameled wire it is usually some small detail of the method of applying the wire or handling it that causes the trouble.

Passing enameled wire through clamps will cause trouble if the wire is clamped too tight. The rubbing or friction generates heat which tends to soften the enamel and, in conjunction with the rubbing action, weakens the covering. Proof that the clamp generates heat can be found by feeling the wire on each side of a clamping block while an armature is being banded.

Transformer or lubricating oils, or any material having an oil base, have practically no effect on enameled wire over long periods of time. The commercial grades of kerosene, benzine, naphtha, and gasoline have, however, a slight effect, but it would take hours of soaking to dissolve the enamel coating. High-test gasoline, turpentine and coal tar products, such as benzol, have a solvent action.

All alkalis have a bad effect on the enamel coating, and the stronger caustics, potassium and sodium hydroxide, etc., soon destroy it. The diluted or weaker alkalis have a less harmful effect on the enamel, and with many of the weaker solutions the enamel will last for a considerable length of time.

It is claimed that the enamel will withstand inorganic acids, such as nitric (sp.gr. 1.25), sulphuric (sp.gr. 1.2), hydrochloric (sp.gr. 1.1), for a normal length of time (immersion for 48 hr.) without injury.

A solution of 10 per cent alcoholic potash will remove the enamel in 30 to 45 min.

Enameled wire will stand a high heat longer than cotton-covered wire, or 100 deg. C. (212 deg. F.) continuously, and due to the higher heat conductivity of the enamel, the dimensions of magnet coils can be decreased.

In general the following are the advantages of enameled wire: A dielectric strength of 600 volts per mil thickness; elasticity of the coating permitting bending around small radii without cracking or peeling; a film that is as hard as consistent with elasticity, to withstand abrasion; close adhesion of the enamel under wire tension; non-ageing or little affected by continued heating and cooling; ability to withstand temperatures that would spoil cotton covering. A high grade of enameled wire will withstand 149 deg. C. (302 deg. F.) without harm. A better space factor for all classes of windings and better heat radiating properties for magnet and field coils, and a lower over-all cost per pound, are other advantages that accrue from the use of enameled wire.

From the data given above, a study of the conditions of manufacturing and operating will determine whether enameled wire will prove satisfactory for a given winding.

In general, starting windings of single-phase motors, fan motor windings, for both direct and alternating current, and direct-current armatures for motors up to ¼-hp., including drills, etc., can be wound with enameled wire.

Table V gives the weights, lengths, etc., of enamel-covered wire. A stock of the sizes from No. 19 to No. 30 inclusive, will be found to cover most repair jobs.

The properties and characteristics of cotton insulation will be discussed in the next article.

Organization of Industrial Plant Fire Departments

By A. A. BECKWORTH
Director, Technical and Industrial Research Division, The Sherman Corp., New York, N. Y.

FIRE-FIGHTING apparatus will be found in nearly every industrial plant, but the advantages of having this equipment at hand are nullified if a corps of trained men has not been established for using such apparatus efficiently in case of emergency. The statement is generally made that the first 5 min. of a fire are more important than the next 5 hr. Attempts have been made in many cases to organize fire brigades, which have been allowed to struggle along for a short while, and then interest has dropped to the point where these brigades are no longer of sufficient value to act as a real protection to the plant. The following outline indicates suitable organization plans for fire brigades in industrial establishments of various sizes.

Unless the plant is very large or unusually hazardous materials are used in the processes, the usual plan is to organize fire brigades from among the working personnel in the plant. The efficiency of such brigades will depend largely on the care with which the members are chosen. Intelligent, loyal, and constructive-minded individuals should be selected who are alert and physically able to undertake the duties involved. Sometimes it is advisable to give preference to men who live comparatively near to the plant, or within hearing distance of the general fire alarm. Where a plant operates more than one shift, brigades should be formed with men from each shift.

Fire brigade members should, of course, be able to speak and understand English, and should be thoroughly familiar with the general layout of the plant and with the various operations performed. Thorough knowledge of stairway locations, elevator shafts, hazardous places, and the nearest fire-fighting apparatus, must be possessed by every brigade member, in order to prevent confusion, or accidents.

With proper constructive education, membership on the fire brigade can be made to be deemed a privilege by the employees. In addition to a badge, brigade members should be provided with passes that will enable them to secure admittance to the plant in case of fire outside of working hours. It is sometimes advisable to add an incentive in the form of a small bonus paid quarterly or semi-annually. In addition, the brigade members should receive their regular rate of pay while on fire drill or duty.

Strict discipline should be maintained among the brigade members,

and failure to report for practice at fire drills, or in case of fire, should involve some fine for the delinquent members. In cases where a bonus is allowed, the record of attendance at drills should be kept and the members penalized for their failure to maintain perfect records. Such fines can be placed in a special fund and used either for purchasing additional equipment, or for entertainment features.

For plants of fairly large size the following general plan of organization is suggested: Fire Chief, Assistant Chief, Company or Floor Captains, Company or Floor Lieutenants, and Brigade Members.

For medium-sized plants, the Assistant Chief may not be needed, while for small plants the officers in the brigade can be the Fire Chief and Company Captains. In addition to the foregoing members of the brigade, it is advisable to have in each organization one or more employees of the Plant Maintenance Department, who are familiar with the plant piping systems and with the operation of all valves. An electrician who has a thorough knowledge of the distribution system in the plant should also be a member of the brigade. These special men should respond to all alarms and be subject to the orders of the Chief or Assistant Chief.

The duties of the Fire Chief are such that they require a man of outstanding caliber and integrity for this position. Some times it is advisable to choose a man who has had previous experience in fire department work, to devote all of his time to the development and training of a brigade. In other cases, or in smaller plants, either the Master Mechanic or foreman of some important department should be chosen for this office. It is necessary for the Chief to have the respect and obedience of the men under him at all times.

The Assistant Fire Chief will act as the aid to the Chief, and closely superintend the training and development of the entire department. When more than one shift is working, the Assistant Chief usually takes care of one shift, but at all times, he is subject to the orders of the Fire Chief. In a medium-sized plant, the Senior Captain may act as Assistant Chief.

The Company or Floor Captains are important officers in the brigade organization. Where the plant is divided into various sections, the Captain is in charge of his particular section; in cases where a plant occupies several floors in a building, it is advisable to have a Captain for each floor. Too much care cannot be exercised in selecting the proper men for Captains. These officials should be workers who are known to be constructive and loyal, and who hold the respect and obedience of the men. Often it is advisable to choose foremen or assistant foremen to fill these positions. Captains should be graded according to seniority and efficiency; they take charge of the brigade in case of the absence of the higher officers.

The Company or Floor Lieutenants are direct assistants to the Captain, and the Senior Lieutenant takes charge of the Company in the absence of the Captain. Brigade members who have shown efficiency in service in the ranks should be promoted to be Lieutenants, and on up through the staff as vacancies occur.

As a general rule, the fire-fighting organization should be arranged so as to utilize the special knowledge and experience of the members. For this purpose, a brigade should consist of several companies, each of which is delegated to handle special kinds of apparatus, and to attend to specific duties in case of fire. Of course, in a very small plant, the brigade companies are usually all-round firemen, but in larger plants, specialization is recommended. Among the special companies to be organized are: Hose Company, Hook and Ladder Company, Chemical Engine Company, Standpipe Company, Hand Extinguisher Company, Pump Men, Special Men and Salvage Corps.

Hose companies should be made up of not less than ten men, including the Captain and Lieutenant. One man should be assigned to hydrant duty, and at least four men for each line of hose operated. Not more than two lines of hose should be assigned to a company. Where only one line of hose is to be operated, the company can be made up of only five men.

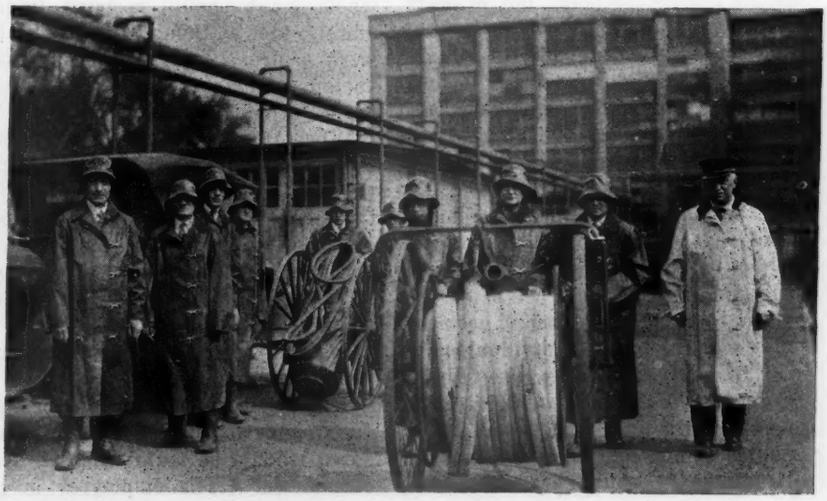
The Hook and Ladder Company should be made up of not less than nine men, including the Captain and Lieutenants. The exact number will depend on the type of building, exposure, and character of operations. The Hook and Ladder Company attends to the placing of ladders, handling and use of chemical extinguishers from trucks, opening of roofs, floors and partitions, wrecking, and such other fire duties as are necessary in the judgment of the Chief.

The members of the Chemical Engine Company are usually six in number, including the Captain and Lieutenant, and they have charge of operating the engine tank, adjusting and manipulating the valves, and recharging. They should be held responsible for keeping the tank fully charged and ready for service at all times.

In plants equipped with an interior standpipe system, a separate Standpipe Company should be organized to handle the hose lines connected therewith. A sufficient number of members, usually not less than

Part of the fire brigade at Bausch & Lomb Optical Company, Rochester, N. Y.

The complete brigade consists of a Chief, two Assistant Chiefs and 29 men, who are grouped into two hose companies, two chemical companies and a salvage corps. The men are provided with rubber hats, coats and boots. The Chief was formerly a captain with the city fire department. This illustration is by courtesy of Foamite-Childs Corp., Utica, N. Y.



six, should be chosen so that at least four men will be available for each of the interior hose lines. In each squad, there should be a valve man whose duties are to remain at the valve to turn the water on and off, and to assist in unreeling the hose line. Where standpipe systems are supplied from gravity tanks or by means of connections with city water mains, there should be a main valve man who is responsible for seeing that the valve between the source of supply and the standpipe system is open or shut as directed by the officer in charge.

The members of the Hand Extinguisher Companies must know the most effective methods for bringing into use the various types of extinguishers provided in the plant. They should know how to handle each type of extinguisher properly, although any worker is permitted to use an extinguisher within his reach as soon as a fire occurs in his immediate vicinity. Where the plant fire system is supplied by local fire pumps, it is advisable that the engineer and his assistant be enrolled in the fire brigade so that they will be able to assure the proper working of the pump in case of fire.

In plants where valuable stock or machinery is likely to be damaged by water, a company of men under the direction of a Captain and Lieutenant should be organized into a Salvage Corps. These men should be instructed in the best methods of covering up stock and machinery, and for saving valuable records. In some cases, suitable equipment such as rubber or fireproof blankets should be provided for the Salvage Corps, and located in a convenient place.

The exact nature of the equipment used by the fire brigades will depend on the size of the plant, but in every case all equipment should be kept in first-class order at all times, and centrally located. Protective clothing for the brigade members is also desirable, and such clothing should be kept in the proper location when not in use. Care must be taken to see that some of the members do not take such equipment home and fail to return it promptly. Gas masks and similar equipment are often provided to cope with special problems that pertain to the individual plant.

The success of any fire-fighting organization depends on the promptness with which the brigade companies report and their efficiency in handling the equipment. Such efficiency can be developed only through frequent and thorough fire drills.

When the Fire Alarm Sounds All Workers Must:

Stop work.
Shut off power.
Stop machines.
Shut off gas and other open flames.
Close doors and windows opening upon or under fire escapes.
Put chairs, stools and other obstructions on top or under benches to clear the passageways.
Form line promptly with front of column facing the usual exit and wait for word of command from Floor Captain.
At the command to march, march in an orderly manner from the building, two abreast, not crowding upon the couple in front, and following the aisle leaders.
Preserve the space in lines between yourself and the couple in front of you.
Retain formation until dismissed or until the line is returned to building.
Don't run.
Don't lag behind, breaking up columns.
Don't scream or make unnecessary noise.
Don't laugh or talk.
Don't cause confusion.
Don't remain in toilet or dressing rooms.
Don't return for your clothing.
Don't try to use elevators.
Don't try to leave the building except in accordance with fire regulations.
Don't fail to assist in carrying out instructions.

It is best to hold drills at unexpected times, and announce them by sounding the usual fire alarm. These drills should be thorough and serious, and every individual in the fire brigade as well as throughout the whole plant should respond immediately, just as though there actually were a fire. The members of the various companies should go through their duties completely.

When the fire drills are first held, there will be confusion and duplication of effort. However, the Fire Chief and his Assistants should soon be able to straighten out matters and to delegate definite performances to each group. The Fire Chief should be directly responsible for all inspections, both of the plant and fire-alarm systems.

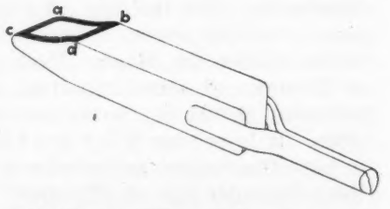
Fire extinguishers should be kept fully charged, and all fire doors, and so on, should be maintained in first-class order. The employees in the various departments must be instructed as to their actions in case of a fire alarm, and the Captains and Lieutenant in charge of the department must see that these rules are strictly obeyed. Usually the Captain will delegate an individual to inspect all washrooms and lavatories when an alarm is sounded, in order that every employee may be duly warned of the danger.

An example of a suitable fire alarm bulletin notice to all employees is given in the accompanying box. Employees should have occasional fire drills also so that they will know what to do when the occasion demands.

Simple Method of Soldering Overhead Work

OCCASIONALLY it is necessary to solder overhead seams and do other work of this sort, and unless the mechanic has previously learned how, he is likely to find difficulty in preventing the solder from running off the hot copper. The operation may be performed by taking an ordinary soldering copper and forging or filing it to the shape shown in the accompanying illustration; it will be noted that there is a slight curvature of the tip between *a-b* and *c-d*.

The copper should be filed smooth on the curved surface and tinned in the usual manner. By touching the edge of the hot copper to a piece of rubber—an ordinary pencil eraser will answer—a narrow ridge of rubber may be built up on the edges.



Soldering copper for use on overhead work.

By filing a soldering copper as shown, and building up a ridge *a-b-c-d* by touching the hot copper to rubber, molten solder may be held up against an overhead seam or other work to be soldered.

This ridge border is indicated by the heavy line in the illustration. This border should be completely carried around between points *a*, *b*, *c* and *d*. The molten solder will then be prevented from running off when the copper is lifted overhead and soldering may be carried out successfully.

New York, N. Y. R. C. NASON.

Dirt Always Makes Trouble

and when it gets inside of a transformer case will cause overheating

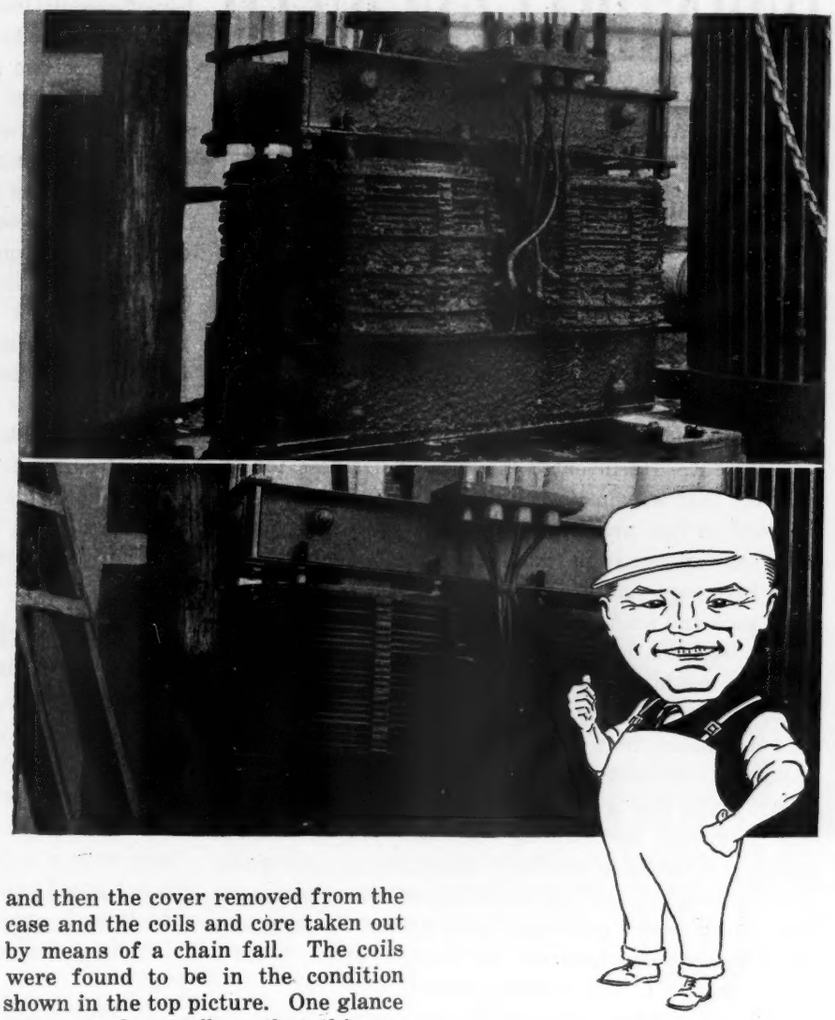
NOT long ago I called on an old friend who has long been associated with one of the largest industrial plants in a well-known southern city. He is an old-timer in operating and maintaining plant equipment, and has acquired a wealth of practical information for which I have a wholesome respect. While sitting in the shade of a bank of high-line transformers, we threshed out some of the problems that every operating man has to solve.

"Long ago," he said, "I came to the conclusion that most of the trouble we operating men have, we bring on ourselves. For one thing, we abuse equipment and neglect it. Furthermore, probably every piece of equipment gives us plenty of warning signs that trouble is brewing, but we are sometimes too careless to notice these signs.

"I have been guilty more than once of doing these very things. The last time it happened was in connection with these transformers. A transformer does its work without making much noise or fuss, even when it is neglected. Nevertheless, it requires a certain amount of attention and when it does not receive this attention, it shows certain symptoms that every operating man should be familiar with. One of these signs is overheating at less than full load.

"For nearly a year the temperature on these transformers had been gradually increasing and we could find no evidence of increasing load. Finally the temperature reached 85 deg. C. at only 80 per cent load, which is the maximum permissible top oil temperature for self-cooled, oil-insulated transformers. We decided to take one of the transformers apart, clean it, and see if we could find anything wrong. These transformers are rated at 600 kva. apiece, and step our power down from 13,200 volts to 440 volts; so you can see that we had a real job on our hands.

"First, the oil was drained off and then the cover removed from the case and the coils and core taken out by means of a chain fall. The coils were found to be in the condition shown in the top picture. One glance was enough to tell us that this accumulation of dirt and sludge was causing our trouble.



"We scraped off as much of the dirt as we could, filtered the oil and then forced clean oil under pressure through the parts of the transformer that could not be reached with a brush or scraper. When we were through cleaning the transformer, I took the picture shown in the bottom illustration.

"Just as we expected, the operating temperature was found to be only 45 deg. C., with an 80 per cent load. This was nearly normal. As soon as possible we cleaned the other transformers in the same way, and have had no more trouble with them.

"Cleaning transformers in this manner is not a regular procedure, and you may tell the other readers of INDUSTRIAL ENGINEER that if their transformers show a tendency to overheat while underloaded, it is a pretty sure sign that they need to be thoroughly cleaned out."

As my old friend says, abuse, neglect, and failure to recognize or properly diagnose the signs that equipment in distress always gives out, account for most of the troubles that operators have to contend with. When you find a plant in which breakdowns of equipment are seldom heard of (and there are many such plants) you may be pretty sure that watching that equipment is a skilled operator whose eye and ear and hand are trained to detect the faintest sign of trouble.

Sometimes those early signs of trouble are hard to detect and may be still harder to interpret. Probably many of you have had some interesting experiences along this line. If so, send me the details and we will start what the doctors call a clinic and discuss some of those cases.

Practical Pete

INDUSTRIAL ENGINEER
Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories
G. A. VAN BRUNT, *Managing Editor*

The Genius of Charles A. Coffin Will Live Long in the Electrical Industry

WHEN Charles A. Coffin, founder of the General Electric Company and long its president, passed away a few days ago, the electrical industry lost one of its most forceful and talented leaders.

Mr. Coffin was not an inventor, but he was a human dynamo in the business and financial sides of electrical development. He invented methods of business for an industry that was in its beginnings when he came into it. And in this process he displayed a depth of originality and imagination that is usually attributed to artists, inventors, and great engineers. He was a master of finance and succeeded well in undertakings in which most other men would probably have failed. He used the same methods, exercised the same imagination, the same inventive power and the same rare vision in the field of finance that Edison has shown in the field of applied science and engineering.

Mr. Coffin was a master organizer. His great work was, of course, the building up, from many component parts, of a far-flung electrical organization in which he was the guiding spirit as well as its chief inspiration. It was his attractive personality and proven capacity as a great leader in the industry that brought about, in 1892, the formation of the General Electric Company by the consolidation of the Thomson-Houston Company with the Edison General Electric Company. By this amalgamation of interests, the difficulties of a complicated patent situation were largely reduced, which ultimately gave to the electrical industry for the first time stability and the opportunity for development on sound lines.

Mr. Coffin has left the stamp of his genius on the electrical industry. His death brings to an end a career of achievements of which any man might well be proud. His services to science, progress, and industrial efficiency will be remembered as long as the industry which he helped to create survives.

Without Records of Past Performance It Is Impossible to Measure Progress

FROM his first experience in industrial plants, every operating man is continually impressed with the necessity of securing uninterrupted operation. Practically his entire time is directed toward the prevention of something which might cause a breakdown, or in getting the equipment back into service afterward.

Comparatively few such men, however, know how well they are progressing toward the achievement of their aim—continuous operation—because they keep no usable records of what they are doing. Keeping a number of cumulative records takes time and many operating executives do not have much office assistance.

There are two records, however, which any man who desires to show regular improvement in his results should keep. These are cumulative and periodic records of man-hours in his department and also the hours-out-of-service of the machines for which he is responsible. The first of these, should, of course, take into account extensive new construction and variations in production in order to make the tabulations comparable. Such records, if kept up regularly, will not require much time to maintain, and the few minutes spent in studying them as the notations are entered will be well invested.

It is advisable to have such records plotted in the form of curves for ready reference and for ease in comparing data taken at different times. Use of such charts will be a big help in showing a plant man how well he is doing his job and the progress he is making.

Money Kept in the Bank Will Not Cut Production Costs in the Plant

HAVING to report that a $50,000 installation of new equipment which you recommended is not producing the expected results, is a job that the most stout-hearted might well dislike. When the Plant Engineer of a well-known industrial organization was forced to make such a report some time ago, his superior merely said, "Yes, I know you are sorry, and you need not take the time to explain just why it doesn't work properly. Go ahead and do whatever is necessary to make it right."

It turned out that a slight rearrangement of the equipment, with the expenditure of a comparatively small sum for additional devices, was all that was needed to make the installation perform even better than had been expected.

The attitude that was shown in this present instance is typical of this organization. The management has always not only placed complete confidence in the engineering and operating executives, until conclusive evidence has been given that this confidence was not merited, but it has likewise been willing to make any expenditures that could reasonably be expected to reduce operating and production costs. If it can be shown that an investment will produce a 4 per cent return, the expenditure is approved without argument. The executive who has proposed the change is then given every chance to make his project a success. Even in the face of apparent failure, his efforts are viewed with a sympathetic understanding that cannot help bringing out the best that is in him and, in the long run, seldom fails to produce the desired results.

In consequence of this far-sighted attitude, the men are encouraged to submit their ideas for consideration, with the result that many good plans are put into operation every year. The combined effect of all of these

betterments has been to place this company in such a dominant position that the management does not have to worry about rising labor costs or price competition.

A penny-pinching attitude toward expenditures for needed equipment, or anything else that will improve operating conditions, may serve to keep down the capital invested, but it will never help any plant to make a reputation for efficiency of operation.

Do You Welcome the Exchange of Operating Experiences?

A CONTRIBUTOR to INDUSTRIAL ENGINEER, in some correspondence regarding an article in which he discussed the solution of a difficult operating problem, recently made the following interesting statement:

> It has been my experience that the average operating industrial engineer is altogether too reticent concerning problems which he encounters in his work, and in his solution of them. Much must be done by these men toward improving operating conditions and reducing production costs. The dissemination of the solution of more of the problems met in the everyday activities of industrial engineers will tend to aid other men with similar responsibilities in obtaining a broader viewpoint and the equivalent of a practical experience in such problems without many of the disheartening features connected with the school of hard knocks.

This man not only visits other industrial plants to pick up new ideas, but welcomes other men to his plant, as he knows that they have had experiences which may be new to him. His ability to build up his own experience by seeking additional information from others is, no doubt, responsible for a good deal of his success in fitting himself for the promotions he has had.

The pages of INDUSTRIAL ENGINEER are open for the discussion of operating problems and ways of solving them. The arrangement of the editorial pages into articles and departments makes it possible to discuss simple as well as more complicated problems and other topics that are of interest to the operating executive in industrial plants. Now is a good time for those who have been receiving the benefit of the experiences of others through these pages to contribute some of their own experiences.

Unsafe Protecting Devices Are Often Worse Than None at All

MANY times auxiliary equipment, which is not a part of the operating mechanism and so is not absolutely essential to its continued use, is neglected because of the feeling that "it does not have to be fixed right away." Safeguards of all kinds, and fire-fighting equipment, in particular, are often neglected for this reason.

A safeguard is put on a machine for the purpose of protecting from injury the operator or anyone who comes too close to the working parts. A guard which does not function is of no more value than no guard at all. In many instances, such a guard is an extra hazard in that, due to its presence, the operator may rely upon it and at the critical moment find it ineffective and so suffer injury.

Fire-fighting apparatus is another type of equipment, the presence of which implies its availability for instant service. Altogether too often, the empty extinguishers or the battered thread on the hose couplings are not discovered until an emergency arises, when their worthlessness may be responsible for a serious loss.

Much of the responsibility for seeing that safeguards and fire-fighting equipment is always in operating condition rests on the men in the maintenance and operating departments. They should realize that they are not through with repairing a machine until the safeguards are replaced and adjusted. Also, that their duty has not been discharged until every fire extinguisher has been refilled and replaced, after use.

No guard to life nor property is of any value unless it is capable of rendering 100 per cent service.

Are You Getting All You Should From Your Arc Welding Equipment?

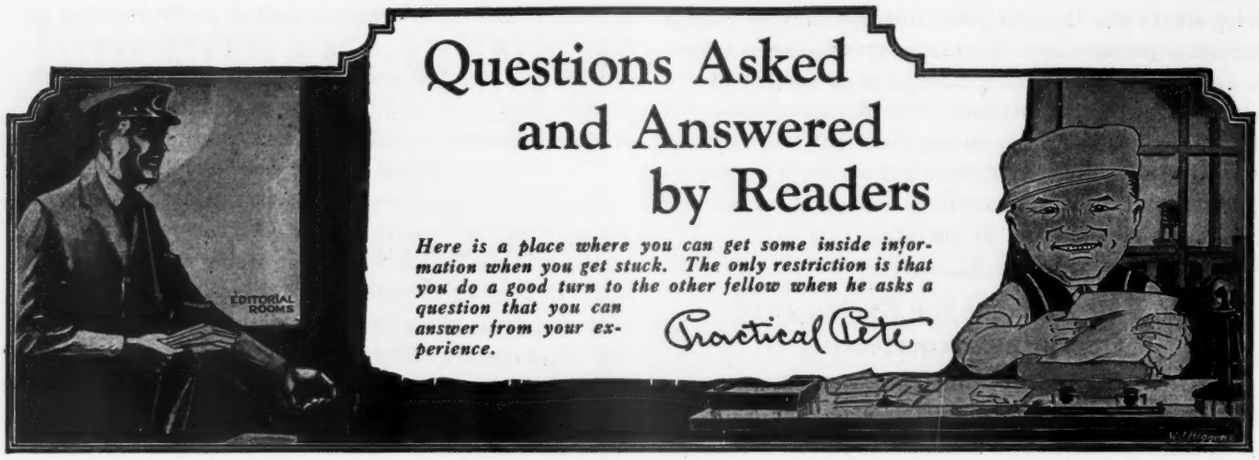
ARC WELDING has been with us for a number of years and has received recognition in many industrial plants as a means of repairing broken parts. However, one may well wonder if it is getting the recognition that it deserves. Are you getting all that you should from your arc welding equipment?

Arc welding equipment is an Aladdin-like glue pot, so to speak, which furnishes us with a means of sticking pieces of metal together much as though they were paper. This means that not only can broken parts be stuck together, but new parts can be manufactured. In most cases these new parts will be made from steel instead of cast iron. The result is that standard steel shapes obtainable in any steel warehouse can be cut and welded together to fabricate much of the shop equipment, such as benches, put up small buildings, repair old machine parts, or make new ones, and so on.

A rough pencil sketch of what is desired is all the instruction that an experienced welder needs to have in order to make a very serviceable and rugged job from welded steel members. This eliminates the draftsman, the pattern maker and the foundry; it cuts down the storage of patterns and the inventory of cast-iron parts. A job that would ordinarily take days now becomes a matter of minutes. The resultant saving in time, money and reduced delay to production is worth much consideration.

Arc welding is long past the experimental stage; it has reached the point where progressive plant executives are not only using it as a means of making large reductions in repair and maintenance costs, but also in cutting costs of installation and erection. Many plants are using it in regular production with large savings in time and money.

If you have not already done so, it will pay you to investigate thoroughly the savings in time, material and money that are possible by the use of arc welding.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Bearings in Wet Locations—It is necessary to operate one of the bearings of a washing device under water. We have not been able to lubricate this bearing and have had considerable trouble due to extensive wear from lack of lubrication and dirt in the water. Babbitted bearings have always been used but I should like to learn the experience of readers with other types of bearings operating under conditions somewhat similar to this. Perhaps someone can suggest a lubricant or method of application which will work. I shall greatly appreciate any information that readers may give.
Des Moines, Iowa. L. D.

* * * *

Operation of Electric Refrigerator—Would there be any objection to using brass valves, pipes and fittings, instead of copper, between the compressor and cooling coils of a small electric refrigerator, similar to a household unit, that uses sulphur dioxide as the refrigerating medium? What material is best suited for use as packing and gaskets? What kind of lubricating oil is best adapted for the compressor? What pressures should be carried on the intake and on the discharge when the compressor is running, and when it is not running? What is the best method of charging a unit of this size? I shall be very grateful for any information that readers can give me on these questions.
Oak, Neb. H. L. M.

* * * *

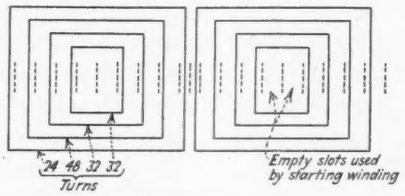
Changing Speed of Induction Motor—I have a 10-hp., 1,200-r.p.m., 220-volt, three-phase, 60-cycle, Westinghouse squirrel-cage induction motor that has 54 slots and 54 coils having a span of 1-and-8. Each coil is composed of 15 turns of two No. 16 d.c.c. wires in parallel. The winding is six-pole and is connected two-circuit star. I wish to reconnect this winding so as to have the motor develop 10 hp. at 1,800 r.p.m., when used on the same supply as before. Can some of the readers tell me how to reconnect the motor to obtain this result?
Chicago, Ill. C. R.

* * * *

Trouble with Storage Battery Charging Generator—We are having considerable trouble due to the reversal of polarity on a 50-kw., 120-volt, interpole generator which is used to charge storage batteries on vehicles. The machines were tested for grounds by means of a Megger and a heavy leakage to ground through the acid-soaked benches in the battery charging department was discovered. Having remedied this, the generator was started and immediately the voltmeter read backwards with no load on the machine. We checked the leads from the machine, but they were of such size and so taped together that it would be impossible to reverse them by mistake. We tried to re-excite the field, but could not; so the leads were reconnected so as to reverse them at the generator and not disturb anything at the switchboard. The generator worked satisfactorily for about three days, when the polarity again reversed itself. We reversed the generator leads to their original position and since then the machine has been operating satisfactorily. I do not know what caused this reversal of polarity and should like to have readers give me their suggestions.
Sacramento, Calif. J. T.

* * * *

Method of Determining Chord Factor—I shall appreciate receiving any information from readers concerning satisfactory methods of finding the chord factor for the following winding. The winding is on the stator of a ½-hp., 110-volt, 60-



cycle, single-phase induction motor. The stator has 36 slots and four poles and is arranged with a starting winding. The main winding is connected as a whole coil, concentric, as is shown in the accompanying diagram, which shows two pole groups.
Milwaukee, Wis. J. M.

* * * *

Grouping of Wires in Conduit for Two-Phase System—I have installed some 3-in. conduit runs, to be used for two-phase power supply circuits. These conduit runs are about 25 ft. long. In them I wish to place 500,000-circ. mil. cables and since it is possible to get only three cables of such size in a 3-in. conduit, it will be necessary to group the cables in two conduits. Will it be satisfactory to place the two A-phase cables in one conduit and the two B-phase cables in the other? In a three-phase system, this should not be done; hence, I am doubtful about doing it with two-phase cables. Would it be preferable to place one A-phase cable and one B-phase cable in each conduit? If so, which of the two B-phase cables should be placed in one conduit with the first A-phase cable? Please give me some information on these points.
St. Lambert, Quebec, Can. J. M.

* * * *

Will This Generator Operate Satisfactorily at Increased Speed?—We have a Westinghouse, Type C, 50-hp., alternating-current motor having a full-load speed of 850 r.p.m., which we plan to use in driving a General Electric direct-current 55-hp. 725-r.p.m. 110-volt generator. We would like to couple these two units directly together instead of making a belt-driven unit. This would necessitate running the 725-r.p.m. generator at a speed of 850 r.p.m., or an increase of 17 per cent in speed. I should like to learn from readers whether or not this generator will operate satisfactorily at this speed, and also whether the increased voltage delivered by the generator can be reduced in any way so as to obtain the original voltage generated at 725 r.p.m.
Hartford, Conn. H. V. D.

Answers Received To Questions Asked

Method of Checking Bearing Alignment.—I should like to know how to check the alignment of bearings on machines having three or more bearings supporting the same shaft, or where two shafts are coupled together by means of rigid couplings. An example of this is a three-bearing, motor-generator set or a large, heavy-duty motor or pump having a pedestal bearing in addition to two regular bearings. I shall appreciate any suggestions that readers can give me for doing this work.
Chicago, Ill. F. B.

The problem of F. B. in the alignment of relatively short shafts is considerably different from the alignment of long coupled shafts, such as line-shafts. Usually, the parts of such machines as F. B. has in mind which are available for lining up are very short, and often the shafts are completely hidden beneath couplings.

In the case of a motor-generator set, about the only place to do the aligning is on the couplings. If these cannot be removed except at great expense, the tests must be made on the peripheries and between their opposing faces. Such tests presuppose that the faces and rims of the couplings are true with the axes of their respective shafts; if they are not, they must be turned or ground true before the tests are of any value. Couplings may have been machined concentric with their bores but the commercial allowance on bores and on shaft sizes may be such that the insertion of the driving key will pull them considerably off-center by the time a check is made at the outer surface.

Alignment of shafts can be checked on flange couplings that are true and of the same diameter by the use of a steel rule and paper feeler or thickness gage. It is first necessary, however, to remove the bolts which fasten the flanges together. The rule is placed successively at the top and bottom and at the two sides of the couplings. While resting the edge of the rule on one-half of the coupling, a paper feeler is used between the far edge of the rule and the other half of the coupling. If the paper is tight at all four points it is safe to assume that the shafts are in line, after having made a check test by turning the machines over one-half revolution. A further check is made by applying the feeler between the flat

faces of the couplings at the same four points.

With flexible couplings, the space between the two halves may be more than the range of the common mechanic's thickness gage and it must be supplemented by a block that nearly fills the space, or such a block may be filed to an approximate fit and used with a piece of paper as a feeler.

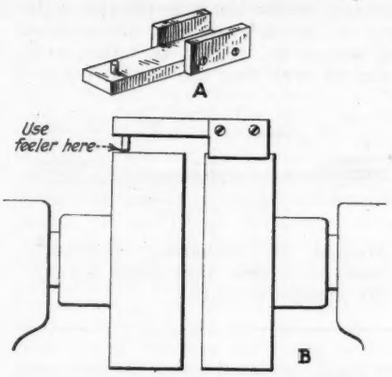
Such a test as described does not level up the machines and this point must be taken up separately. When a set is factory-built and the two units are mounted on a common base, the latter can be leveled up and there is every assurance that the machine is practically level. On small machines of this type, it is sometimes possible to drop a line from the outer shaft ends to the base and to do the same thing on the stub shafts in the center, just back of the couplings, and then to compare these with a line scribed on the base (or a straight-edge) which is used as a datum line.

Couplings are seldom perfectly true and of the same diameter. In that case a simple tool for lining may be constructed, as shown in illustration *A*, by attaching two pieces of flat iron to a piece of cold-drawn steel and putting a short pin in the outer end. A similar tool may be machined out of a solid block of steel, iron, or brass. The reason for making the tool of this general shape is to form a V-block which will keep itself parallel to the axis when placed on a shaft or other round part. The difficulty of doing this with a piece having a single bearing line, such as a rule, is the chief objection to the first test, as described above. With the concave or V-block, this difficulty is overcome. The method of using this block is shown at *B*. Such a tool is cheap to make and very useful on jobs of this kind; it is equally useful on couplings and shafts and it can be made in any length suitable for the work in a particular plant.

All machines should be leveled up. When a set is mounted on a common base, or bedplate, there is always a chance to do the leveling on a planed upper surface of this. Otherwise, one has to clear the shaft of couplings or pulleys and level up by it. It is sometimes possible to provide a foundation sufficiently level so that other checking is not necessary. When a truly level plane has been established in one of the ways named, the only deviation from this will come from wear in the bearings.

On motor-generator sets where the shaft length is above the average, the foregoing check at the couplings does not line up the machines closely enough. It is obviously poor practice to line up a 10-ft. shaft on the periphery of a coupling whose radius is only 7 or 8 in.

Illustration *C* shows a more accurate method of lining from a coupling. The device used consists of two pieces of light steel angles which have one leg of each bent at right angles to form a foot which is attached to the rim of the coupling by two screws. These angles can be any length that will swing without touching the floor or bedplate; long angles will permit making a more accurate check because it is further from the center. Angles are

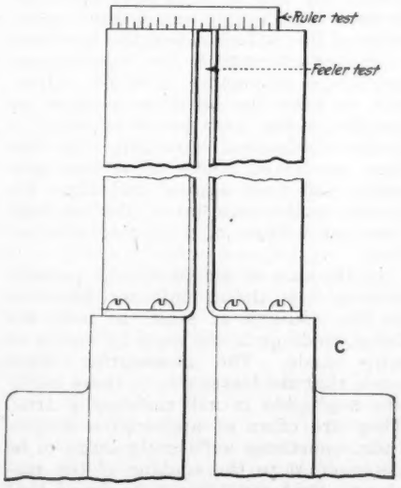


This simple gage, A, is used with a feeler as at B for checking alignment of short shafts at the rim of couplings.

light, stiff, and cheap; an hour's work will put these in place and the accuracy of alignment which may be obtained makes them worth more than this slight effort. Also, the angle irons may be kept and used on other couplings and also for periodic checking of the alignment.

If the angles are made the same length, the ends should be squared off so that the test with a steel rule can be made at four points of revolution approximately 90 deg. apart. If one angle is made longer than the other, or the two flanges are not of the same diameter, scriber marks can be made on the longer one and the machines will have to be shifted until these marks made at opposite points finally coincide. The other check to be made with these angles is by use of a feeler between them. This test should also be made every 90 deg. These same tests may be applied to solid flange couplings, although it would be necessary to loosen or remove the bolts which hold them together.

It might seem that undue emphasis has been placed upon the apparently simple test of checking up at the four 90-deg. points, as indicated in the above paragraphs. However, with electrical machinery, all that there is to work



Where the shafts are over 10 ft. long this type of gage is used at the couplings to check alignment.

with in most cases is the coupling and it is an impossibility for two shafts to have these several checks come out right unless the shafts are in line. Hence the method forms a check especially adaptable to such jobs.

For machines having an outboard bearing, it is essential that the shaft be true and its truth known for a certainty. If there is a worn spot inside a bearing or a bend in the shaft, however, all the painstaking labor of lining up will be in vain.

Where it is known that the shafts are perfectly straight and have no worn spots inside the bearings, one of the easiest ways to check alignment of the bearings is to secure a length of shafting of the same diameter and try this in the three bearings, which presumably are of the split type, divided horizontally. With the caps off, a level (having a grooved base) is used at several points to determine the straightness of the shaft as it lies in the cradles formed by the three half-boxes.

The following method of checking against bent shafts assumes that some of the previously mentioned tests for alignment of bearings have been made. Bent shafts are difficult to detect on motor-generator sets and other types of machines with three bearings because of the armatures, rotors, or other parts which are mounted on the shaft. One of the easiest ways to check up a bent shaft in such cases is to secure a length of straight shafting of the same diameter and try this in the three bearings as described above.

The foregoing is one of the easiest ways to check up a bent shaft, either the machine shaft or the length of shafting used for trial purposes. A bend in the piece of shafting will be plainly visible and readily caught if the level be tried on it at one or more points, trying it first "as is" and then trying it as turned over 180 deg. Assuming that it has been found to be straight by this test and the bearings have been scraped or lined up to it, the real machine shaft should lie in the half bearings in the same way and a check with slips of paper or the use of a little spotting material rubbed on the journals would quickly show if there were any bend in this piece.

This special piece of shafting can also be used to spot up the bearings, in the same manner as when bearings are being scraped in. The outboard bearing is shifted, however, instead of being scraped in. If it is possible to turn the machine over (rotate the shaft), its own shaft may be used in much the same way for spotting as a means of determining alignment; where the journals are of two or more diameters, this will have to be done.

Strips of paper laid under the shaft, when it is raised, will also show a high or low bearing. A strip of paper at each side of the shaft at each bearing will show lack of alignment sideways. These strips should extend in an inch or two between the shaft and its bearing and be pulled after the shaft is lowered again. The necessary adjustments may then be made and these tests repeated until the alignment is perfect.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Armature Bands Overheat. — Five bands are used on a 220-volt, d. c. armature with which we are having trouble. The armature coils slope very sharply and to prevent the outside bands from slipping off the ends of the armature, the winder soldered copper strips across the bands so as to tie them together. Six ⅜-in. strips were placed parallel to the coils and spaced at equal distances around the armature. The bands as well as the copper strips are well insulated from the armature winding, but the bands and particularly the copper strips become very hot, presumably from some induced current. I would like to know what causes this heating and how it may be prevented. If it is induced current that causes the heating please explain what causes this current. Is there any way in which I can tie these bands together that will not cause the heating referred to?
Oelwein, Ia. L. T. M.

Answering L. T. M.'s question, the copper strips parallel with the slots are conductors moving in live fields, so that when they are shorted by the armature bands, they act just like the main conductors in the armature, and have current generated in them. This often happens when wide bands are soldered into one sheet band. If L. T. M. will replace these copper strips with steel strips, which have eight times as much resistance, he can likely cut down the current flow enough to prevent heating. W. MONTELIUS PRICE.
Seattle, Wash.

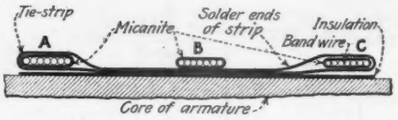
* * * *

If L. T. M. had stated the size of the armature with which he is experiencing trouble from hot armature bands, and had also given the width of the individual bands, it would be possible to give him more definite information.

The heating of the bands, however, is caused by eddy currents generated in them by the constantly changing magnetic flux through the armature conductors. This flux cuts through the bands and is constantly changing from zero to maximum in one direction, back to zero, and up to maximum in the opposite direction as the armature rotates.

L. T. M. states that all five bands on this armature have been electrically as well as mechanically tied together. This, no doubt, is the cause of the excessive heating of which he complains. These bands are probably each narrow enough so that if they were not connected together, they would not overheat any more than is common with this portion of an armature. It seems to be necessary to tie these bands together to prevent the outer ones from slipping off the armature.

I would advise L. T. M. to insulate the tie strips connecting the bands together by means of flexible micanite as shown in the accompanying illustration. He should first put down his tie strips around the armature, being careful that insulation is placed beneath each tie strip to prevent it from touching the core. Over these tie strips is placed the insulation that goes underneath the bands. The outer bands, *A* and *C* in the accompanying illustration, are then wound on. Insulation should now be placed over the top of the bands *A* and *C* and the tie strip can be bent over this insulation and carried over to the center of the armature where the two ends of the strip may be soldered together, as is shown. Insulation may now be placed over the double thickness of the tie strip for the center band *B*, which may then be insulated and wound on. From the illustration it can be seen that the bands *A* and *C*



Method of anchoring armature bands over coils that slope toward the armature shaft.

are both insulated from the tie strip, and the tie strip holds these two bands from slipping off the ends of the armature by reason of being anchored by the band *B*. J. M. WALSH.
Assistant Chief Engineer,
Gurney Elevator Co.,
New York, N. Y.

* * * *

I was very much interested in the question asked by L. T. M., as I have had several experiences along the same lines that he has encountered. Although it is good practice to band the head of the armature, using clips spaced at short distances around the periphery, trouble may sometimes be caused if the same method is used for banding the core. This is especially true if the magnetic field of the machine is very strong because the trouble will be exaggerated owing to the eddy current generated in the band. I recall very distinctly one instance in which the heat generated by the eddy current was so great that after the armature had been repaired and rebanded, the solder holding the banding wire was melted. The generator was rated at 500 kw., 250 volts, 500 r.p.m., and had 25 banding clips spaced at intervals of 10 in. around the periphery of the core.

To overcome this trouble, new bands were wound around the core, but this time the clips were spaced the same distance apart as the poles of the machine. As this was an eight-pole machine, four clips were used on each band and they were spaced 90 deg. apart. By this arrangement the clips on each band are at any instant under poles of like polarity, and the tendency to induce currents in the band is reduced to a minimum. It is also advisable to have the bands as narrow as possible, using more bands in order to obtain mechanical strength. In the case mentioned above, after the new bands had been applied and clips attached to the core bands, the machine operated without any trouble whatsoever.

In the case of direct-current railway motors, it is almost universal practice, in this country at least, to hold the rotor windings in the slots by means of wire bands. The assumption often made that the losses due to these bands are negligible is not necessarily true. They are often of appreciable magnitude, sometimes sufficiently large to be detrimental to the cooling of the machine. By tests it has been found that the band losses vary according to the 1.7 power of the frequency and from the 1.35 to 1.8 power of the induction, depending upon the width and type of band. These losses were found to be chiefly due to the change in the radial component of the flux as the band passes by the pole tip. For the average band, about 15 per cent of the losses (hysteresis and eddy current) are due to the tangential flux in the band. In large railway motors, losses may under certain conditions amount to 2 or 3 kw. HARRY J. ACHEE.
Chief Electrician,
City of Woodward,
Woodward, Okla.

* * * *

In reply to the question by L. T. M. regarding the tying of armature bands with copper strips, I would say that this is always unsuccessful due to the cutting of magnetic lines of force by the strips from one band to another and consequent building up of current in the bands and the connecting strips.

The best way to place these bands is to use increased tension when putting on the band wire. Then it will be unnecessary to link the bands together. Some winders place too much insulation under the bands and when the armature heats up this insulation shrinks and the band becomes loose. Use as little insulation as possible and pull the band wire as tightly as possible. L. T. M. might try linking the bands with strips of bright tin which can be easily soldered and are known to give better results than copper strips. LEE F. DANN.
Chief Electrician,
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

Method of Marking Rubber Gloves. — I would appreciate receiving any information concerning satisfactory methods of marking linemen's rubber gloves which are periodically subjected to electrical tests, as I wish to mark on the gloves the date of the last test. These gloves are used constantly for both inside and outside construction work. Any help that readers can give me will be greatly appreciated.
Lowell, Mass. J. H. J.

In reply to the question by J. H. J., our system of glove testing for a public utility company is to have the gloves tagged with a man's name and consider the gloves as belonging to "John Smith." The record is kept accordingly and John Smith is held responsible for his own gloves.

Each man has two pairs of gloves which are tested at regular intervals for each district. The only requirement necessary in using this method is that the tester should be careful to prevent the tags from being mixed.
Chief Electrician, E. J. MORRISSEY.
Western United Gas & Electric Co.
Aurora, Ill.

* * * *

Answering J. H. J., I would say that in marking rubber gloves that are subjected to periodic tests, one is confronted with more or less of a problem. About the easiest way to mark each glove is to turn back the cuff and enter the date of test on the inside of the glove in ink, but this record is likely to be destroyed if the gloves are in constant use. A better method is to assign each man a pair of gloves, to be kept in a light-weight canvas bag. This

bag can be numbered by painting the desired numeral on it. A record is then made of the bag numbers and at stated intervals the gloves are all tested, and the condition of gloves, bag, and leather protectors for the gloves entered on a chart for that purpose, and filed for permanent record. PHIL D. COMER.
San Bernardino, Cal.

* * * *

How Much Insulation Should be Put on Cable Splices?—Can some reader tell me how many layers of varnished cambric tape should be used for insulating the splices of lead-sheath power cables of the following voltages: 110, 220, 440, 550, 4,000 and 20,000 volts. Do you think some other kind of tape preferable for this work? I shall be grateful for any information that readers can give me regarding the amount of insulation that should be used when splicing cables of the above voltages, and also for any other information or suggestions as to the best method of handling it.
Toledo, Ohio. S. J. M.

In reply to S. J. M.'s question regarding insulation for power cables, I would suggest using one layer of splicing compound (unvulcanized rubber tape) covered with half-lapped friction tape. The rubber tape should be pulled on tightly enough to stretch it to about half its regular width. This insulation is for use on 110-volt cables. One layer of varnished cambric can be substituted for the rubber, if desired. The rubber will stand about 300 volts per mil of thickness. The varnished cambric tape will stand about 1,000 volts per mil of thickness. The tensile strength of either of these tapes is not great and both should be protected by friction tape or some other protective tape. The average roll of varnished cambric tape is from 0.010 in. to 0.015 in. thick by ¾ in. wide. Other widths and thicknesses can be obtained.

All cables below 600 volts are insulated practically alike, using two or three layers of varnished cambric tape half-lapped and covered with cotton or friction tape. The cotton should be painted or have hot paraffine poured over it because this tape when untreated has a dielectric strength of only 250 volts per mil, but when treated the breakdown voltage is 1,000 volts per mil. On 4,000-volt cables use from three to five layers of half-lapped varnished cambric tape, covered with one layer of treated cotton tape.

The 20,000-volt cable is in the extra-high potential class and should have about six or eight layers of varnished cambric tape and one or two layers of treated cotton tape. Over all conductors one or two layers should be wrapped before the lead sleeve is slipped in place. If the joints are not wiped, several layers of P. & B. tape should be applied over the whole and each layer heated with a torch before another is applied. This class of joint should be painted with P. & B. waterproof paint also. This makes a watertight joint and will remain so if painted at intervals. GRADY H. EMERSON.
Birmingham, Ala.

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General Electric Bulletin No. 87000E recommends for voltages not exceeding 25,000 volts, the use of General Electric splicing rubber to a diameter equal to that over the insulation on each conductor. This is then followed by tape to give a total thickness equal to 1½ times the thickness of insulation on a single conductor. The length of the taping should be 25 times the thickness of the insulation measured from the center of the splice outward or a total of 50 times the thickness for the entire length of splice, tapering the thickness in proportion to the distance from the center. This is followed by taping the individual conductors with a band of varnished cambric in order to separate them. The thickness of this band should equal the thickness of the insulation on the single conductors of the cable. The three conductors are then taped together with two belts of varnished cambric 1½ in. wide and 1½ times as thick as the cable belt, following this with linen twine to prevent unwrapping.

In straight runs of cable I have used a layer of rubber tape followed by varnished cambric, half lapping each layer and painting each layer with a coat of air-drying varnish. This makes a very stiff joint, but it can be made extra tight. The whole secret is in tight taping and uniform lap.
Chief Electrician. E. J. MORRISSEY.
Western United Gas & Electric Co.,
Aurora, Ill.

* * * *

Determining Number of Poles in Stator by Use of Compass.—(1) Can some reader give me a simple method of determining the number of poles in two- and three-phase stators when the nameplate is missing? That is, can I pass direct current from dry cells or other source through the winding and use a compass to locate the poles? Or will it be necessary to trace out the winding? How should I go about tracing out a winding to find the number of poles? (2) Why does the terminal on the positive pole of a storage battery corrode, while the negative terminal does not? I shall appreciate your help.
Worcester, Mass. R. S. T.

In reply to R. S. T., I would say that the best way to test a.c. motors for polarity is as follows:

In a two-phase machine, connect one phase to a source of direct current, preferably a lamp bank in series with a 110-volt, d.c. line, and test with a compass for the number of poles. Reversal of the compass needle will indicate when the compass passes from one pole to the next. The number of poles in both windings is the same. The lamp bank also should not permit more than 50 per cent of load current to flow through the winding and usually a much smaller current is sufficient.

In a three-phase, star-connected machine, one of the test leads may be connected to any one of the motor terminals and the other one should be connected to the star point.

In a delta-connected machine, the phases should be separated at one of the terminals, and the test leads should be connected across any phase.

One way to determine the number of poles without the compass test is to count the number of coil groups on the stator and divide that number by the number of phases.

The third method is to use the formula, $P = (f \times 120) \div$ r.p.m., where P = number of poles and f = frequency. As an example let us consider a 60-cycle machine having a speed of 1,800 r.p.m. This machine will have $(60 \times 120) \div 1{,}800 = 4$ poles.
Brooklyn, N. Y. MICHAEL REUTER.

In reply to R. S. T.'s question, I would say that if the motor is in running condition he can find the r.p.m with a speedomotor and by the accompanying table he can tell the number of poles the motor has.

Speeds and No. of Poles of Induction Motors

No. of Poles	60 Cycle Synchronous R.P.M.	25 Cycle Synchronous R.P.M.
2	3,600	1,500
4	1,800	750
6	1,200	500
8	900	375
10	720	300
12	600	250
14	514.2	215
16	450	166.6
18	400	187.5
24	300	125
36	200	83.3

A check may be made also with a compass. Pass a direct current of approximately 5 per cent of the full-load current rating through one phase of the winding; then slowly move a compass around the inner periphery of the stator. On the stator mark the polarities as indicated by the compass. The number of times the compass reverses indicates the number of poles.
HARRY J. ACHEE.
Chief City Electrician,
Woodward, Okla.

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In answer to the question by R. S. T., I would advise that a simple and convenient method of determining the number of poles in a winding is by the use of a compass and battery or other source of direct current, taking care to limit the current flow safely within the carrying capacity of the winding. First, remove the rotor, if this has not already been done. If the winding is three phase and star-connected, connect one lead of the d.c. supply to one motor lead and the other d.c. lead can be connected to the star point, which is the junction of the phase-winding ends.

Then by placing the compass inside the stator and moving it from a given starting point, following around the stator closely to the laminations back of the starting point, it will be observed that the needle has swung through a number of half-turns. Count the number of times the needle has reversed its position; this number will be the number of poles the motor has and will be the number which was stamped on the motor nameplate.

If the motor is three phase, delta-connected, the procedure will be the same as with the star winding except that the delta must be opened and the d.c. supply connected to only one phase. Then use the compass as before.

For a two-phase, four-wire motor connect the d.c. supply to the two motor leads of one phase. For a two-phase, three-wire motor, connect the d.c. supply across the ends of one of the phase windings and count the number of poles as indicated by the compass.
Muncie, Ind. GEORGE CROPPER.

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Replying to R. S. T.'s inquiry, the number of poles may be easily found in two- or three-phase machines by checking the speed of the motor and making a few simple calculations. If a 60-cycle

motor runs 3,600 r.p.m., the winding must be two pole; if 1,800 r.p.m. on 60 cycles, it is four pole; 1,200 r.p.m. for six pole; 900 r.p.m., eight pole; 720 r.p.m. for ten poles, and so on. To obtain the number of poles, simply divide the number of alternations per minute by the r.p.m. The number of alternations per min. for 60 cycles =7,200, for 25 cycles it is 3,000. Then for 60 cycles the equation will be $(60\times 60\times 2)\div$r.p.m. and for 25 cycles the equation will be $(25\times 60\times 2)\div$r.p.m.

In case the motor is burned out and the nameplate is missing it will be necessary to check the winding. First, count the number of slots or coils and if the motor is three phase, divide the number of coils by three. This gives the total number of coils per phase. Next count the coils in series per pole-phase group and divide this number into the number of coils per phase. This result is the number of poles. The equation is (number of slots or coils ÷ number of phases) ÷ number of coils in series per phase group. The following is an example of a three-phase stator having 96 slots and 96 coils: 96 ÷ 3 = 32 = number of coils per phase. Then, as there are four coils in series to form a pole-phase group and since 32 ÷ 4 = 8 it follows that the stator has eight poles.

The number of poles can also be found by connecting two or three dry cells across one phase of the winding and checking around the inside of the bore of the stator with a compass. Each reversal of the needle indicates a pole and equal numbers of both north and south poles will be found.

Answering R. S. T.'s second question, there are several explanations in regard to the corrosion of the positive terminal of a storage battery. The most likely one is the action of electrolysis. This builds up a greenish-looking substance common to all batteries. The cause is probably the action between the terminals as they are not absolutely sealed from the air and moisture creeps in, causing the deposit to form on the terminal. This can largely be avoided by a generous application of vaseline on the terminal before making the connection.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co.,
Donnacona, Quebec, Can.

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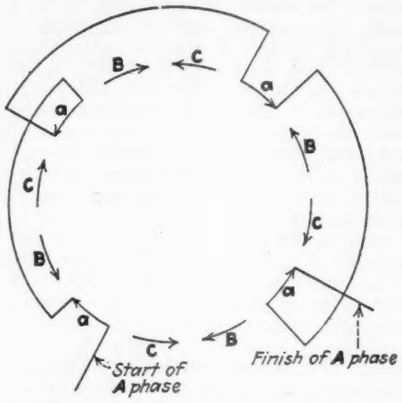
The number of poles in a stator can be determined by connecting a battery to the terminals and using a compass to determine the number of poles—as a matter of fact, this is a common test which is frequently employed.

If the machine is star-connected, the battery is applied to the start and finish of a phase, but if it is delta-connected the delta is opened and the battery connected to the two ends opened. A piece of chalk is used to mark the compass deflection on the core as the compass is moved over each pole. The number of times the compass reverses per phase indicates the number of poles.

Another method is to determine the number of coils in a group by counting the series connections. If there are no series connections, then there is but one coil per group; but if two series connections are used, then there are three coils to the group, etc. This does not take into consideration odd groupings, in which groups may have different numbers of coils in them, each circuit or the complete circuit being evenly balanced by proper distribution of coils.

As an example, let us take a machine having 72 slots and, as there are two coil sides to a slot it stands to reason



Method of finding number of poles in a stator winding.

A compass is used to determine the polarity of each pole-phase group, the reversals of the compass indicating when it passes from one group to the next. The number of pole-phase groups divided by the number of phases equals the number of poles.

that there are 72 coils. We find two series connections which make three coils per group and since it is a three-phase machine then it follows that (72 coils ÷ 3 coils per group) ÷ 3 phases = (72 ÷ 3) ÷ 3 = 8, or the machine has eight poles.

In the illustration I have shown a three-phase, four-pole stator with two coils per pole-phase group or a total of 24 coils. The arrow on each pole-phase group indicates the polarity as obtained by a compass. Note that adjacent arrows oppose each other. The number of arrows per phase indicates the number of poles. Only the A phase is shown; B and C are connected likewise and are single-circuit. If this were a two-phase job the arrows would be somewhat different in that they would be in groups of two.

The winding illustrated will have one series connection and is generally referred to as a 1-and-4 connection, or a top-to-top, referring to the fact that the coil side in the top of the slot is connected to the coil in the top of the slot on the next group.

I would suggest the R. S. T. get in touch with the McGraw-Hill Book Co. for books on armature winding. He will find it entertaining and of great benefit in understanding what is going on inside his stators.

The corrosion referred to in the second question is caused by the natural sulphation of the positive terminal, caused by discharging too far or allowing the battery to stand for a long period without charging; wrong specific gravity of electrolyte will also tend to cause this corrosion and it can be cured by correcting the above and by the application of vaseline to prevent sulphation. A method of preventing this formation is overcharging at periodic intervals, but this should be done in a careful manner.

Chief Electrician, E. J. MORRISSEY.
Western United Gas & Electric Co.,
Aurora, Ill.

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In answer to R. S. T.'s query, I would say that if a d.c. power supply is handy, it is quite an easy matter to find out how many poles a stator has, by testing with a compass.

On a star-connected motor, stick a scriber, or any other piece of metal that has a sharp point, into the star connection; tie one line of the d.c. to it, and the other end to one line lead. Now pass the compass around the stator on the inside, and mark the reversals of the compass N and S or + and — on the stator at the point at which the reversals take place.

If you want to check a stator for polarity, you will have to repeat this operation on the remaining two legs, leaving the same d.c. line on the star connection until the test is completed. Always withdraw the compass from the stator before you break the d.c. circuit or you may reverse the polarity of the needle of the compass and upon testing the succeeding phase, misleading results will be obtained. When the test is completed, the polarity marks will alternate. Let us assume that on a certain stator we have made a total of 18 marks, three + marks and three — marks for each of the phases. This proves there are 18 pole-phase groups in the whole stator.

As we were testing a three-phase stator, we must divide the total number of groups by the number of phases therein. Therefore, the stator has 18 ÷ 3 = 6, or six poles. Such a stator will have a synchronous speed of 1,200 r.p.m. on 60-cycle power.

The formula to figure this out is as follows: (120 × 60) ÷ 6 = 1,200 r.p.m.

If it were a 50-cycle machine it would run at (100 × 60) ÷ 6 = 1,000 r.p.m.

A 25-cycle machine would run, (50 × 60) ÷ 6 = 500 r.p.m.

I believe it is much quicker, however, to count the groups, either by the number of leads, or the connections coming out of the winding. There are two leads to a group, one top lead and one bottom lead. Count either all tops or all bottoms, but not the two together. Divide the number of leads counted by 3 for a three-phase stator or by 2 for a two-phase stator, to obtain the number of poles.

This can be done by just removing the end shield on the lead side, while with a compass you would have to slip out the rotor. Also with a delta connection, a compass test might be misleading, unless you open one side of the delta.

To find whether a stator is star- or delta-connected, proceed as follows: If the leads that connect the stator winding with the line connect to only one group, it must be a single-circuit star. If a line lead connects with two groups, the winding is either a two-circuit star or a single-circuit delta. If the two groups come out of the same phase it must be a two-circuit star. To check this, call one group A and count A, B, C, A, B, C, and so on,

until you get to the other group that connects with that line. If this is an A group then you know it is a two-circuit star winding; otherwise, it must be a single-circuit delta winding.

A delta-connected winding will always have twice as many group connections to the line as it has circuits; that is a two-circuit delta will have four group connections to the lines, while a two-circuit star has only two and so on. NICHOLAS J. WEISS.
West New York, N. J.

* * * *

Answering the question by R. S. T. I would say that this can be done by applying direct current to the winding. The direct current voltage should be sufficient to cause about 30 per cent of the full-load current to flow.

In checking a three-phase, star-connected winding for the number of poles, the test is made as shown in Fig. 1. The positive lead of the direct-current supply is connected to the *A* lead of the winding and the negative to the star connection. The compass is now moved slowly around the bore of the stator and its deflections noted, marking the bore with chalk, using arrows to indicate the polarity. After completing the test on one phase, the positive lead is shifted to the *B* lead and then to the *C* lead, leaving the negative wire always connected to the star connection. After checking all three phases there should be a circle of arrows pointing in alternate directions as indicated in the diagram.

On a delta-connected winding the test can be made with one set-up as shown in Fig. 2. Here the delta connection is opened at any one of the leads (in Fig. 2, it is opened at the junction of *A* and *B* phases) and direct current applied so that current flows through all three phases in series. If the compass is now passed around the bore of the stator it will indicate alternate polarities just the same as in the test on the star-connected winding.

On a two-phase winding, direct current is applied to the ends of each phase separately, Fig. 3, as *A1* and *A2* or *B1* and *B2*, in which case the correct polarities would be as indicated in the diagram; that is, the pole groups alternate in pairs. Figs. 1 and 2 are both six-pole windings giving a speed of 1,200 r.p.m. at 60 cycles, while Fig. 3 is an eight-pole winding for 900 r.p.m. at the same frequency. P. JUSTUS.
Chief Electrician,
Chandler Motor Car Co.,
Cleveland, Ohio.

When the nameplate of an a.c. motor is missing and all connections are in place, even though the motor is burned out and has to be rewound, the number of poles in the winding may be determined as follows: On two-phase motors there are twice as many coil groups as there are poles; likewise on a three-phase motor there are three times as many coil groups as poles. Therefore, by dividing the number of coil groups by 3 the number of poles may be ascertained on a three-phase motor, and on a two-phase machine there would be one-half as many poles as coil groups.

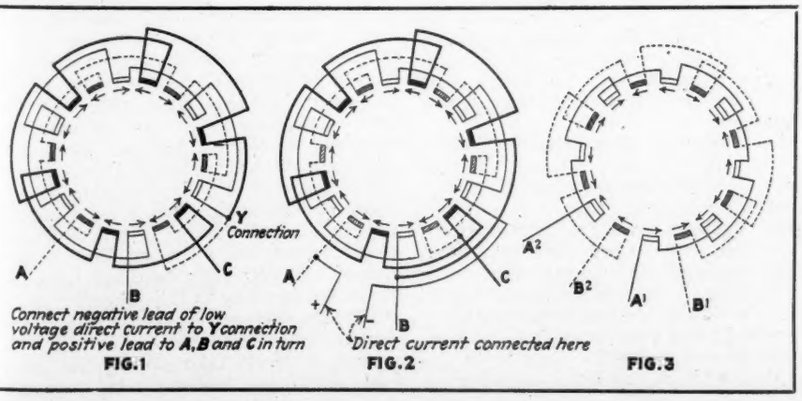
The coil groups can easily be recognized by the stubs or series connections from each individual coil to the others in that particular coil group. A coil group is seldom less than two coils, in which case there would be one stub; a coil group of three coils would have two stubs, and the remaining two ends would tie to the next coil group in that phase or to the line, in some parallel connections. The number of stubs will be one less than the number of coils forming that particular group.

In counting the groups in a stator of which the nameplate is gone, it is a good idea to check up the number of coils in several groups to be sure that the number is the same in each group. If they are found to be unequal, it is a bastard grouping and the poles will not divide into the number of coils by an even number, a six-pole machine with 48 coils being an example. Here 18 groups are necessary, but 18 goes into 48, 2⅔ times and this would necessitate an unequal grouping. There would be, accordingly, 12 groups of 3 each and 6 groups of 2 each. These would, of course, have to be arranged so that there would be an equal number of coils in each phase, and also so that they would be equally spaced around the stator.

Occasionally, the poles of a storage battery corrode, which is caused by the action of sulphuric acid on some metal other than lead, especially copper. This is probably due to the battery post being loose. R. S. T. will find that the negative will also corrode, but not so much as the positive. Just why the positive corrodes more than the negative I have been unable to find. Commercial vaseline applied to these terminals will prevent this and washing the top of the battery in a solution of common soda dissolved in water will be of aid. A weak solution of commercial ammonia is also good.
Birmingham, Ala. GRADY H. EMERSON.

Direct current is passed through the windings and the number of poles found with the aid of a compass.

Fig. 1 shows how the direct-current should be applied to a three-phase, star connected winding while Fig. 2 shows how it is applied to a delta-connected winding. Fig. 3 shows the method of connecting for a two-phase winding.



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Drying Out Direct-Current Motors.—One of our largest steel works was recently flooded, due to the breaking of a dam. About 500 direct-current, shunt-wound, 250-volt motors, ranging in size from 10 to 250 hp. have been under water for 10 days. Our problem is to dry out these motors in the shortest time. The greatest difficulty encountered is in drying out the shunt-field coils. Drying out in an oven is rather slow, due to the large number of motors that must be taken care of. I would greatly appreciate learning from readers what methods they would suggest for drying out these motors, particularly the field coils.
Bressoux, Liege, Belgium. P. V. H.

In reply to P. V. H.'s question referring to the drying out of d.c. motors, the writer had a similar experience after a mine explosion in the West where the 500-volt motors used had been under water for several weeks. These motors ranged in size from 5 to 200 hp.

We proceeded at first by stripping the outside insulation off the coils and washing them with benzine. The coils were wiped dry and put in an electric oven used for baking armatures. However, this process was too slow, since the coils dried out on the outside surface only.

It was urgent that we have these motors in operation at the earliest possible time; so we arranged to connect the shunt coils inside the oven in series with a resistor, applying about 75 per cent of normal field voltage, while the oven temperature was regulated at 180 deg. F. for 6 to 12 hr., depending on the size of the coils.

After this treatment the field voltage was raised to normal, the oven temperature was gradually raised to 220 deg. F. and the coils were baked for about 2 hr. The coils were then tested, dipped in a baking varnish, allowed to drip, and baked again for 10 hr. at a temperature of 190 deg. The series and interpole coils were treated as above, except a heavier resistor was used for controlling the increased current required to raise the temperature of the heavier copper. We experienced difficulty in removing the sludge and mud from the armature and interpole coils, but found that by first drying (not baking) the windings and applying a benzine wash, the mud was easily removed. WILLIAM J. MILDON.
Supt. Power & Equipment,
Madeira-Hill Coal Mining Co.,
Philipsburg, Pa.

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Answering P. V. H.'s question, if a generator or other source of power is not available I would suggest that he dry out one of the motors in any convenient manner and use it as a generator. After removing the armatures of the other motors the field windings can be dried out by connecting a number of them in series and passing cur-

rent from this generator through them. This scheme will enable him to save time, if the motors can be grouped conveniently. Care must be taken, however, to limit the current to a safe value so that the windings will not be overheated. Covers should be used for each machine, to keep the heat in. Also, grids or other heating devices may be placed in the base of each unit to furnish additional heat.

For drying out the armatures, I suggest that these be covered with an asbestos pad. Resistance wire of suitable length and size for the voltage employed should be wound over the asbestos covering. When current is passed through the resistance wire it will heat up enough to dry the armatures out very satisfactorily. The asbestos covering is needed as an insulator, as well as to give protection from local overheating.

Vigilance must be exercised during the drying-out process to prevent damage. A temperature of 175 to 185 F. can be safely used and maintained constant by the use of a rheostast or by regulating the generator voltage.

Chief Electrician, E. J. MORRISSEY.
Western United Gas & Electric Co.,
Aurora, Ill.

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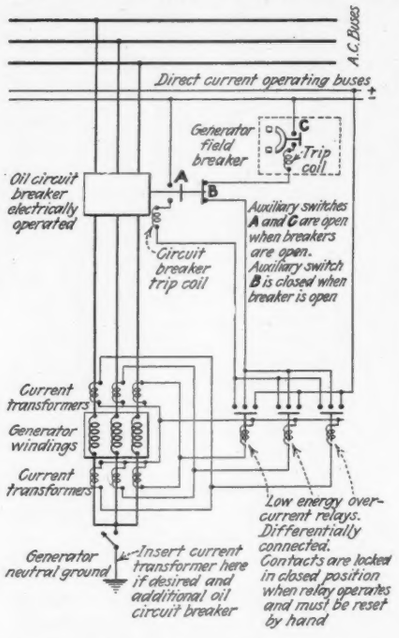
Overload Protection for Generators.—(1) We have installed in our power plant, two 2,000-kva. generators and two 4,000-kva. generators all of which are rated at 2,300 volts, three phase, 60 cycles, 3,600 r.p.m., and are driven by steam turbines. What protection should we have on these generators? Should reverse power relays, or overload relays, or both be used? Are these relays necessary and also what other protection is required on these machines? The four machines are arranged to be paralleled together and quite often all of them are running simultaneously. (2) We have installed one 50-kw., 125-volt, motor-driven generator which operates in parallel with two 100-kw. steam-driven exciters for supplying field excitation for synchronous motors. Should we have circuit-breaker protection on these machines and if so, should a three-pole circuit breaker be used? I shall appreciate any information that readers can give me regarding these questions.
Detroit, Mich. R. J. B.

The following are my answers to R.J.B.'s questions regarding the overload protection required for generators.

(1) The accepted practice, when a number of generators are operated in parallel, is not to install any protection against direct overloads on the generating equipment. This practice is due to the possibility of one of the generators being tripped through faulty relay setting or operation, thus throwing more load on the other generators. This condition is particularly liable to occur when the load is variable and the prime movers driving the generators have governing characteristics which are markedly different.

Experience indicates that protection should be installed only for faults in the generators themselves. This protection should operate as quickly as possible and immediately disconnect a generator when the trouble occurs. For this purpose the so-called differential protection is most used. To apply this, it is necessary, however, to have the ends of each phase winding brought out of the generator winding so as to permit the insertion of current transformers. While this is possible in a new generator, those of the older type usually have only three line terminals and the bringing out of the other three may not be a simple or an easy matter. In these cases a reverse power relay could be installed, but the protection would not be as good as with the differential method.

The accompanying diagram shows the connections for the differential protection of a three-phase generator. The connections are shown for the condition when the main oil circuit breaker is open. This form of protection consists of balancing the current leaving the generator at one end of the winding against the current flowing through the same section but at the other end of the winding. This scheme of protection is usually accomplished by connecting a current transformer at each end of each phase winding, connecting their secondaries in series, and then connecting a current relay across these secondaries, as shown in the diagram. As long as the secondary currents are equal, no current will flow through the relay windings. Any leakage of current, however, to other phases or to ground will upset this balance, and send current through the relay. The relay in turn operates to trip the circuit breaker and disconnect the faulty equipment.


A.C. Buses
Direct current operating buses
+
Generator field breaker
C
Trip coil
A
B
Oil circuit breaker electrically operated
Auxiliary switches A and C are open when breakers are open. Auxiliary switch B is closed when breaker is open
Circuit breaker trip coil
Current transformers
Generator windings
Current transformers
Low energy over-current relays. Differentially connected. Contacts are locked in closed position when relay operates and must be reset by hand
Generator neutral ground
Insert current transformer here if desired and additional oil circuit breaker

Connection scheme for protection of generators.

This scheme provides what is known as differential protection and puts the generator out of circuit in case of faults developing in the winding. It is deemed inadvisable to protect the generator against straight overloads due to too much load.

The scheme as shown has limitations in that it will not always protect against short-circuited turns in the generator winding. Also, it will not always protect against a low-resistance ground on account of the very small unbalance and also because the very low setting of the relay required would be too sensitive for practical operation. A ground relay can be used if the generator is not connected directly to the bus, but with all machines stepping up separately through transformers there is no trouble. In general the scheme shown is fairly satisfactory without special equipment.

It should be understood that where machines have grounded neutrals and all connect directly to the bus, only one neutral can be closed at one time. Should the generators be operated with a grounded neutral, the differential protective scheme will allow the installation of an additional relay to protect a generator from a fault to ground by inserting a current transformer in the ground connection, as shown in the diagram.

The relay used in connection with differential protection is the same as the straight overload type of relay except that it operates at a much lower current. One manufacturer makes a relay for this purpose that operates at a range from 0.5 to 2.5 amp.

(2) For exciters operated in parallel, experience indicates that a reverse-current relay is sufficient protection. Regarding the question of circuit breakers, nothing is said of the type of machine in service, but under any condition for a straight shunt or compound-wound machine a two-pole breaker on a two-wire excitation system is satisfactory.

C. OTTO VON DANNENBERG.
Designing Engineer,
General Engineering & Management Corp.,
New York, N. Y.

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In answer to the questions asked by R. J. B., I have the following to say:

(1) The general practice, and the one which is more reliable for a power plant installation, is to have the generators installed without overload protection. This practice should be followed when using only one generator, or when there is more than one, for it gives an assurance of continuous operation without the danger of shutdown. Alternating-current generators of the size and capacity which R. J. B. has, are usually well built and solid enough to withstand severe strains and stresses. The winding, as a rule, is lashed to prevent the twisting and raising action caused by overloads. The generators will stand without injury several times full-load current if it is of short duration.

In case of a short-circuit, turbine-driven, alternating-current generators will deliver about 15 times full-load current for a few seconds after which the current will drop to about one and a half to two times full-load current. This is because of two factors: The reactance of the generator winding, and the degree of field excitation that the exciter will furnish under the circumstances at the time. These things make generators of this class able to take care of themselves in case of extreme overloads, or at least, until an attendant can correct the trouble. If over-load protection were used and trouble should occur on the system, such as a short-circuit, ground, failure or stalling of a large motor, or a heavy line surge, enough current might be taken to cause the overload relay to trip, thereby shutting down the entire plant, while if the generator did not have overload protection, it would take care of the overload until the overload relays on the

feeder switch protecting the circuit on which the trouble occurred, could operate and open the switch, thereby cutting off only the one circuit and thus preventing a station shutdown. With proper operation and attention, it will not be necessary to have either the overload relays or the reverse power relays for generator protection. The power plant operation will be more satisfactory without them, as far as power troubles are concerned.

(2) If the motor-driven, direct-current generators and the turbine-driven exciters are used to excite the fields of the alternators, there should be no circuit breaker protection on them for if the circuit breakers should open from any cause whatsoever, the alternator field would be killed which would result in a complete interruption to the electrical power output of the station. If the exciters are being used to excite the field of the synchronous motors only, circuit breakers could be used if desired, but even for motor field excitation it would be better not to use a circuit breaker, for if by chance the breakers should open while the motors were loaded, the motors would take such a large amount of current that the windings would be ruined within a very short time unless proper overload protection were provided for the motors.

Muncie, Ind. GEORGE CROPPER.

* * * *

Trouble with Solder. — We are having considerable trouble in making soldered joints hold on rectangular wire in coils that are subjected to rather high temperature, such as might be the case in series field coils and brake series coils. We have tried an 80 lead—20 tin solder, but it melts due to the excessive heat. Can our readers suggest any methods that will enable us to join these wires together in a manner that will stand rather high temperature? I shall be very much indebted to any reader who can give me some help in this matter.

Norton, Va. W. H.

Replying to W. H.'s question in the March issue, I would say from past experience that the trouble is due to high resistance in the joints, rather than high operating temperatures. If W. H. will use a 95 per cent pure tin solder, I feel quite sure that his troubles will disappear.

While this type of solder has a much lower melting point than the kind he is using, it also has a much lower resistance, thus causing less local heating at the joint. I have had exactly the same trouble with field and armature connections and in both cases it was eliminated by the use of 95 per cent tin solder. R. R. SCHELLENGER.

Electrical Engineer,
Elk Horn Coal Corp.,
Wayland, Ky.

* * * *

In answer to W. H.'s question relative to trouble with solder on series field and brake coil connectors, the usual custom is to allow the ends of the wire to extend far enough beyond the coil being wound to double the wire and use a suitable connector or clamp which will eliminate the soldering process. If this is inconvenient, the splice or connection can be brazed with a spelter composed of four parts zinc to one part copper. This alloy melts at a temperature of 1,275 deg. F. The melting temperature can be raised by addition of copper.

To braze, it is important that the spelter should melt at a lower temperature than the material to be brazed and that the ends of the wires should be thoroughly cleaned. Apply a small amount of a good brazing flux and keep the neutral flame of a small acetylene torch moving over the part to be brazed, to prevent it from fusing. When space is limited, it may be advisable to use pieces of sheet asbestos to prevent overheating of the insulation.

WILLIAM J. MILDON.

Supt. Power & Equipment,
Madeira-Hill Coal Mining Co.,
Philipsburg, Pa.

* * * *

Changing 25-Cycle Brake Coil to 60-Cycle Service.—I am having a little trouble in changing over a brake coil from 25-cycle to 60-cycle service. This coil is used on the brake on the hoist motion of a 10-ton traveling crane. The coil was originally wound with about 1,400 turns of No. 21 magnet wire for 25-cycle service. I have rewound the coil using 800 turns of No. 15 wire, but the coil only lasted a few days before burning out, and it does not seem to have the lifting power of the old coil when used on the 25-cycle service. This coil was formerly connected across a 440-volt, 25-cycle power supply and will be used on the same voltage for the 60-cycle service. The diameter of the smallest turn is about 2 in. and the largest turn about 4 in. The coil is in reality a solenoid with a plunger working through the center of it. Can some reader tell me how many turns to use on this coil and what size of wire should be used in order that I may use it on the 60-cycle power supply?

Green Bay, Wis. H. B.

In reply to H. B.'s question, the number of turns in the coil is, for practical purposes, inversely proportional to the frequency, thus: $N_1 : N_2 :: F_2 : F_1$, where N_1 and F_1 represent the original number of turns and frequency, respectively, and N_2 and F_2, the new number of turns and frequency. Then $(1{,}400 \times 25) \div 60 = 583$, say 600 turns.

The corresponding larger size of wire to use is No. 17. Since the winding volume is not given, I checked this, based on s.c.c. wire and find that No. 17 wire will not quite fill the winding space. Therefore, each layer of wire should be well insulated from the succeeding layer by dry insulating paper, to make the diameter of the coil as large as conditions will permit to reduce the heating.

The coil apparently is used on a shunt brake, intermittent duty and should be dipped or impregnated in insulating varnish. In many cases it is cheaper to obtain the proper coil from the manufacturer of the apparatus as it is oftentimes difficult to wind and treat coils properly with the equipment at hand.

Bobbin-wound coils are dipped in heated insulating varnish and then baked for several hours. Form-wound coils are impregnated by being placed in vats with the insulating compound and subjected to pressures up to and including 100 lb. per sq.in. The coils are then removed and baked for several hours in an 18- to 20-in. vacuum. This treatment removes all of the moisture and keeps the coil from absorbing moisture. Also, the insulation between adjacent turns and layers is very much improved. E. H. LAABS.

Engineering Dept.,
The Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

In reply to H. B., if this brake coil is wound with 585 turns of No. 17 wire, I think no further trouble will be experienced.

Whenever the line frequency is increased 2.4 times, the number of turns has to be decreased accordingly, since increasing the frequency increases the impedance.

As the resistance is very small in comparison to the reactance the turns will have to be reduced to $(25 \div 60) \times 1{,}400 = 583$ turns. No. 21 wire has an area of 810 circ.mils and in order to increase the size 2.4 times, the area would have to equal $810 \times 2.4 = 1{,}944$ circ.mils. No. 18 wire has an area of 1,624 circ.mils and No. 17 has 2,048 circ.mils; therefore, No. 17 would be the better size to use. However, as the same amount of work is expected of the coil, that is, foot-pounds to be lifted, and since it is also operated on the same voltage, the size of wire is not so important as might at first be thought.

The reason why the rewound coil did not stand up under the new frequency was because the number of turns was not decreased sufficiently to reduce the impedance to its original value. This cut down the current flow below its former value. With the consequent reduction in flux, the coil was not able to lift the plunger high enough so that the reactance would cut the current to a safe value.

NICHOLAS J. WEISS.

West New York, N. J.

* * * *

H. B.'s problem is one which can be solved by using the old transformer formula, maximum flux = (volts $\times 10^8$) $\div$ (4.44 $\times$ turns $\times$ frequency). To obtain the same lifting power from the solenoid on a 60-cycle supply as on a 25-cycle supply, the voltage remaining constant, it will be necessary to keep approximately the same value of maximum flux.

It is evident from the formula that the number of turns in the coil must be changed inversely as the frequency, that is, the number of turns are decreased in the same proportion that the frequency is increased. Therefore, the correct number of turns for the new coil must be $(25 \times 1{,}400) \div 60 = 584$.

H. B. will be able to see why the lifting power with 800 turns was not so great on 60 cycles as it was with 1,400 turns on 25 cycles. The maximum flux was only $(25 \times 1{,}400) \div (60 \times 800) = 0.73$ or about 73 per cent of what it was before. The reason for the coil burning out with this winding of No. 15 wire was probably the lack of pulling power to raise the plunger to a point in the coil which would make the reactance great enough to cut down the current to a safe value.

A No. 17 B. & S. gage wire could be wound in the coil space very nicely with 584 turns and should give a coil which will perform as well on 440 volts, 60 cycles, as the old coil did on the 440-volt, 25-cycle power supply.

J. M. WALSH.

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Gurney Elevator Co.,
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Electrical Service

around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Comparative Advantages of A.C. and D.C. Motors for Larry Car Service

WHEN larry cars are propelled at constant speed, the question of whether to use a.c. or d.c. motors is often very properly determined by the kind of current available. Alternating current can be used but the following disadvantages will be encountered, some of which can be overcome by proper application and installation of the motors and other equipment.

(1) Alternating current requires the installation of an extra trolley wire or rail with extra insulated supports, guards, and so on, as well as additional labor for installing. (2) The induction motor has a maximum torque for starting and under some conditions would fail to move the load, whereas a d.c. series motor, if correctly applied, would either move the load or slip the wheels. (3) The starting current drawn from the line by a d.c. series motor is much less for the amount of torque exerted. (4) The series motor speeds up under light loads and will propel a light car faster than the a.c. motor. (5) With a series motor it is possible to obtain creeping speeds with either high or low torque. As an induction motor is inherently a constant-speed machine, it has a very steep characteristic at partial speeds and becomes very unstable, particularly at low torque values. (6) In case the supply voltage is low, the torque exerted by an induction motor is reduced to direct proportion to the square of the impressed voltage, that is, if the voltage were 90 per cent of full value, the torque would be 81 per cent. Reduction in d.c. voltage has no effect on the torque of a series motor. All of these objections, with the exception of (5) can be overcome if the motors are properly applied.

It is difficult to obtain slow speed with an induction motor, although slow speed can be obtained by the use of a d.c. series motor with properly designed control equipment. If low speed running is required with high torque, fair results can sometimes be obtained with an induction motor by putting an artificial load on the motor by a solenoid brake and inserting resistance in the secondary. This method is not economical of power and also puts considerable extra wear on the brake. Slow speed and low torque are practically impossible to obtain with an induction motor and the advantages of the d.c. series motor become more pronounced.

An illustration of motor requirements may be seen in a foundry which has a larry car for hauling sand to the leaching boxes, where the sand is poured into the sand boxes, then smoothed over by means of a plow, and finally sprinkled, after which the larry car returns to the sand chute. All of these operations are performed by the car. When hauling the sand, moderate torque and high speed are required. In spreading the sand, high torque and low speed are required. For sprinkling, low torque and low speed are required. Fig. 1 shows the characteristics of a slip-ring, variable-speed, induction motor of the type generally used in crane hoist service. The accompanying table gives the operating requirements of the motors based on the various operations of the larry car.

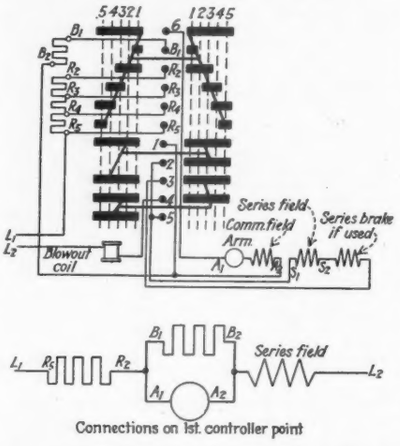


Fig. 3—This shows the controller connections for a series d.c. motor on a larry car.

Comparing the a.c. data in the table with Fig. 1 it will be noted that points *A* and *B* are 96 and 98 per cent speeds respectively. This is according to what one would expect, since the induction motor is essentially a constant-speed machine. In other words the larry car returns empty at only a slight increase in speed. Points *A* and *B* in Fig. 2, which give the characteristics of the d.c. motor, show 140 and 170 per cent speeds respectively. A series motor speeds up under light load and consequently the car will be returned empty for another load of sand at a higher speed.

Referring to operation 3 in the table, it will be noted that the car must proceed under heavy load and at slow speed, because the plow is spreading the sand and the speed should be reduced to approximately 9 per cent. In Fig. 1 it will be seen that 9 per cent speed and 98 per cent torque occur at point *C*. It should also be noted that point *C* occurs on curve No. 4, which is obtained on point No. 4 of the controller shown in Fig. 3. This is a very unstable point as is evidenced by the steepness of the curve. If the torque is increased from 98 per cent to 108 per cent, due to the binding of the car wheels on the track or some other cause, the car will stop. If the torque is reduced 10 per cent due to a slight dip in the track, the speed will be doubled. Referring to the corresponding point *C* in Fig. 2 an increase or decrease in this amount of torque on a d.c. series motor will mean an increase or decrease in the speed of only approximately 1 per cent. This is due to the flatness of the curve which is obtained by a shunted armature connection, as shown in Fig. 3.

In order to propel the car when sprinkling acid, it is required to have a creeping speed of 26 per cent; the torque is then light instead of heavy because the larry car has dumped its load of sand, and the plow for spreading the sand has been raised. For the induction motor, the conditions which caused unstable operation at slow speed and heavy torque have now become aggravated, due to the decrease in

Load and Duty Cycles for A. C. and D. C. Motors in Larry Car Service

Operation	Per Cent Torque A.C. or D.C.	Per Cent of Speed A.C.	Per Cent of Speed D.C.	Points on Curves
1. Propel car at full speed with load of sand	39	96	140	A
2. Propel car at full speed empty	20	98	170	B
3. Propel car when spreading sand	98	9	9	C
4. Propel car when sprinkling acid	20	?	26	D

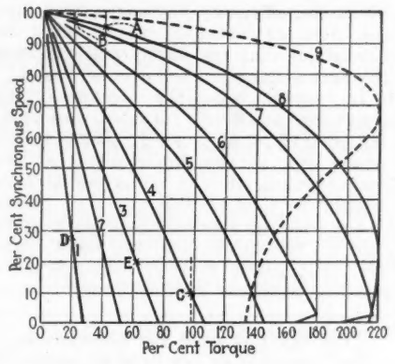
torque. Point *D* in Fig. 1 falls on curve No. 1 which is the first point on the controller. It will be seen that a very small increase in torque will stall the motor and a very small reduction in torque will accelerate the motor to practically full speed. In fact, the speed-torque curve of the induction motor becomes very steep at this low range of torque, so that it is rather difficult to tell the exact speed because of the large variation for a slight increase or decrease in torque. In Fig. 2, point *D* falls on the shunted armature connection curve. As in cases of spreading sand at high torque and low speed, a moderate increase or decrease in torque will not materially effect the speed of the car and for practical purposes may be disregarded.

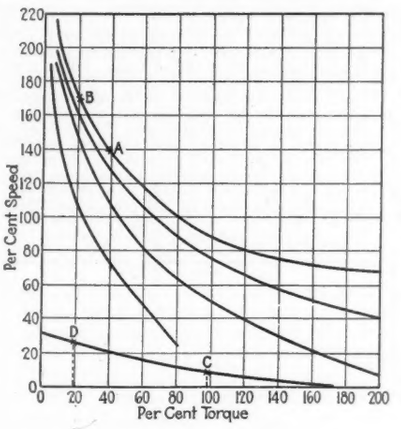
As suggested previously, fairly passable results can be obtained from the induction motor by putting an artificial load on it and inserting resistance in the secondary. This results in placing the operating point on a flatter curve. For example, enough load can be put on the motor by tightening the brake to get 62 per cent of full-load torque and the resistance in the secondary will be obtained by advancing the controller handle to the third point, or *E* in Fig. 1. It will be seen that operating conditions here are much more stable than at point *D* on the same diagram, but do not compare with operating conditions as given for point *D* of the series motor, in Fig. 2. If a very considerable amount of running is done with the brake "on," it may result in excessive wear and heating of the brake shoes. This method should be recommended only for short and occasional operation; it should never be used for continuous service.

With the series motor, it is possible by adjusting the values of resistances R_5, R_2 and B_1, B_2, to get various slopes for the first curve at the bottom of the diagram in Fig. 2 to suit practically any combination of torque and speed that the conditions require. If the values of R_5, R_2 are increased, they will cause this curve to become flatter and to cross the abscissa at a higher torque value. It will also slightly increase the value at which the curve crosses the ordinate at zero torque. Increasing B_1, B_2 instead of R_5, R_2 will have exactly the reverse effect and will give a steeper curve. In this case, it is assumed that the high-torque, slow-speed point *C* is somewhat lower in speed than the low-torque, low-speed value *D*. This lends itself to the slope of the shunted armature curve. If it is necessary to have the high-torque point *C* at a higher speed value than 26 per cent shown at *D*, it will be necessary to use a controller which will provide two shunted armature points.

The use of the shunted armature connection has certain limitations in obtaining a creeping speed. If the speed is so low that a very flat, low curve is required, it may mean a shunted current of high value with a resulting large number of resistance boxes. This would not be economical of space or power.

In the great majority of cases found in the various industries, where a creeping speed is necessary, the requirements





Figs. 1 and 2—Operating requirements for alternating- and direct-current motors in larry car service.

Fig. 1 shows the speed-torque curves for a slip-ring, variable-speed induction motor. The numbers on the curves correspond to the various positions of the controller. Fig. 2, speed-torque curves of d.c. series motor.

are such, however, that the shunted armature connection can be successfully used.

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How to Determine Power Factor with Slide Rule

NOW that the slide rule is losing most of its mystery, some of the practical uses to which it may be put are interesting to know. It is often desirable to calculate the power factor of a circuit, a load, or a motor, when it is not possible to get simultaneous readings in kilowatts, amperes and volts. Most formulas for finding power factor require the use of trigonometric tables; a slide rule, however, will do just as well and is handier to use.

For three-phase circuits, the power factor may be found by using a slide rule and the formula $(a - b) \div (a + b) \times \sqrt{3} =$ the tangent of the angle of which the cosine is the power factor. In this case a and b are either the readings of two integrating wattmeters or the single-phase readings from a polyphase wattmeter. The expression $(a - b) \div (a + b) \times \sqrt{3}$ may be replaced by reactive kva. ÷ kw. when the readings from a wattmeter and from a reactive kilovolt-ampere meter are available. The expressions just given may be solved with or without the slide rule, as desired, to compute the value of the required tangent.

In using the slide rule, the following procedure is required: Set the slide so that the end of the 45-deg. line or the tangent scale coincides with the end of the *D* scale. Then place the hairline against a number on the *D* scale corresponding to the tangent value previously found, and read off the angle on the tangent scale. Since the slide rule has no cosine scale but tangent and sin scales only, the sin scale has to be used. The cosine of an angle is equal to the sin of its complement or its difference subtracted from 90 deg. Therefore, subtract the angle already found from 90 deg. and with the slide in the same position, and the hairline placed against this complementary angle on the sin scale, read the sin value on the *A* scale. This number is the required power factor.

For tangent values below 0.9, the following method, although a little longer, will be found more accurate on account of the difficulty of obtaining accurate readings near the right-hand end of the sin scale, due to close spacing. For any angle, the sin divided by the tangent is equal to the cosine. Following the same procedure as before find the tangent value and read off the corresponding angle on the tangent scale; then on the *A* scale read the sin value of this angle (this is not the complementary angle) on the sin scale. Set the slide to divide this sin value by the tangent value already found and the quotient will be the power factor. Although this method may appear rather cumbersome and requires a long explanation, it will be found easy to apply with very little practice and the power factor can be worked out to within ½ per cent in less than a minute.

A few examples will illustrate the procedure. Suppose you are using a polyphase recording wattmeter to check the load on a motor and you want to know the power factor. Take two single-phase readings by disconnecting either the potential or the current coil, as most convenient, first on one phase and then on the other. We will say that the single-phase readings are 414 and 126 respectively. Substituting these values in the formula, $(a - b) \div (a + b) \times \sqrt{3}$ to find the tangent, we will then have $(414 - 126) \div (414 + 126) \times 1.732 = 0.923$, the required tangent. Now set the hairline at 923 on scale *D*, with the slide placed so that the scale ends coincide; the corresponding angle on the *D* scale will be 42 deg. 40 min., approximately. Since 0.923, the value of the tangent, is over 0.9 use the first method. Subtract 42 deg. 40 min. from 90 deg.; this gives 47 deg. 20 min. Using the sin scale and the *A* scale, read the sin value of the angle 47 deg. 20 min., which is found to be 0.735. This value of 0.735 is also the cosine of 42 deg. and 40 min. and is the required power factor.

Again, if the average power factor of a load is required for say a month from the readings of two integrating wattmeters, which are 72,850 kw.-hr. and 43,710 kw.-hr. respectively, substituting in the formula (72,850 —

43,710) ÷ (72,850 + 43,710) × 1.732 = 0.433, the required tangent. Set the hairline against 433 on scale *D*, as before, and read 23 deg. 25 min., approximately, on the tangent scale. As 0.433, the value of the tangent, is less than 0.9 the second method is more accurate. On the *A* scale read the sin of the angle 23 deg. 25 min., which will be about 0.397. Divide 0.397, the value of the sin, by 0.433, the value of the tangent. This will give 0.917, approximately, as the power factor required.

When it is necessary to find the power factor from the readings of the wattmeter and a reactive kilovolt-ampere meter, all that is necessary is to divide the reactive kva. reading by the kw. reading, the quotient giving the tangent of the angle of which the cosine is the power factor. Then proceed as in the examples given, according to whether the tangent value is above or below 0.9.

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Chart for Determining Horsepower of Slope Hoist Motors

IN COMPUTING the horsepower necessary to operate slope hoists, the cycle of operation is hard to determine, but the following approximate method will give horsepower values sufficiently close for all practical purposes.

The total unbalanced weight to be hoisted may be calculated or estimated. Maximum values should be used if the hoist is to be operated continuously, and if it is to be used only for intermittent service, the motors should be able to carry the overloads for a short time. This is usually taken as ½ hr., and if the motor does not overheat in this length of time, it is assumed that it will be sufficiently large to carry all loads that may be imposed upon it. The selection of the values should be made with due consideration for the limitations of the installation; in some cases even the track and rope friction have to be figured.

Per cent grade is found by dividing the difference in elevation by the distance hoisted. Some difficulty may be encountered when the grade is very flat in some places and comparatively steep in other places. In any event, it is necessary to hoist the load and for that reason one should consider the steepest grade.

Hoisting speed in feet per minute would, under most circumstances, be an average value of the load speed. The maximum value used would be dependent upon the curves and the other physical characteristics of the track. The hoisting speed, per cent grade, and total unbalanced weight are directly proportional to the horsepower necessary for the hoist motor, but the efficiency of the mechanism is inversely proportional to the horsepower.

The over-all efficiency of the hoist will be the one factor that may be increased by proper care and attention and will also be governed by the method of speed reduction used. The over-all efficiency will decrease as the hoist becames older and eventually the apparatus will be uneconomical to operate. Since the efficiency decreases with age, the first or assumed value must be liberal, so that the motor will continue to operate the hoist for several years.

In laying out the accompanying chart, the following formula was used: Hp. = $(W \times P \times V) \div (16.5 \times E)$, where hp. is the horsepower of the hoist motor, W the total unbalanced weight in tons, P the per cent grade, V the hoisting speed in feet per minute, and E the efficiency of the hoist. The per cent grade and the efficiency are used as decimals on the chart.

This chart is used for determining the horsepower required by motors to operate slope hoists.

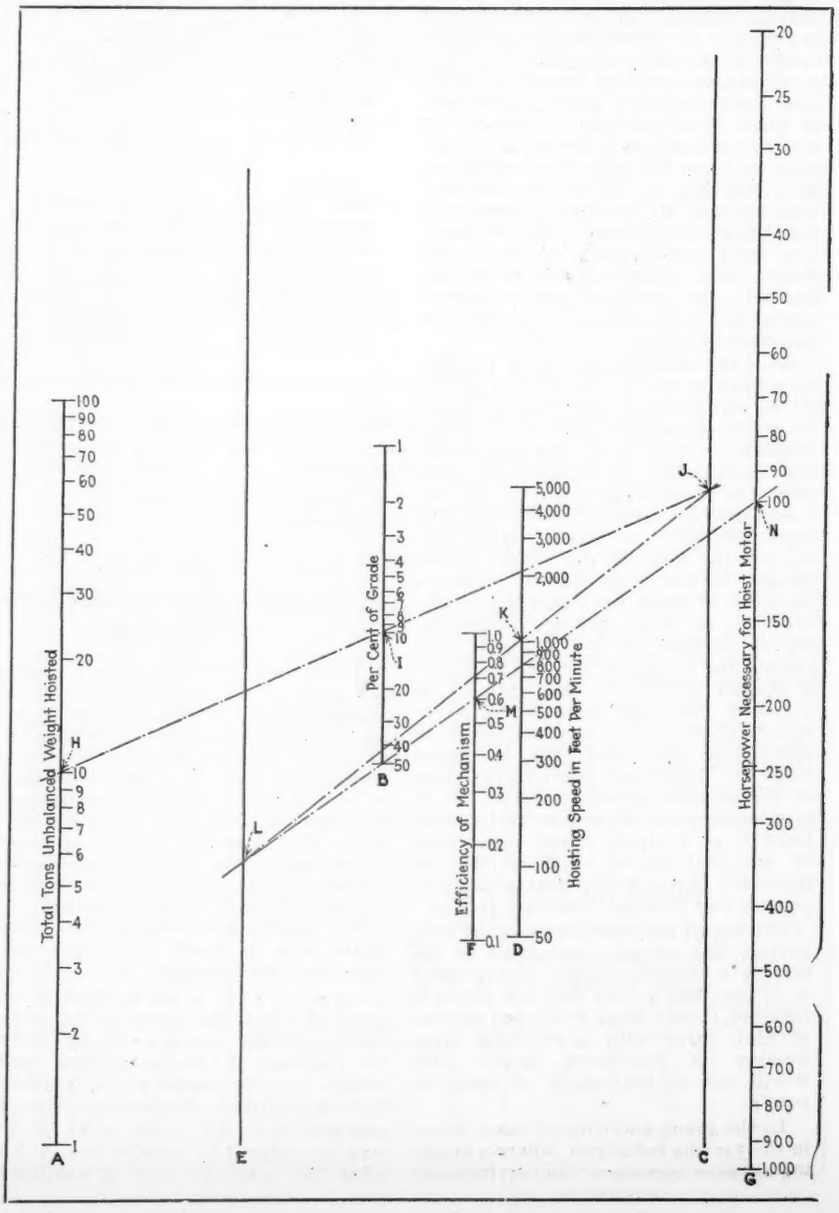
Assume that an unbalanced load of 10 tons has to be hoisted up a 10 per cent grade at 1,000 f.p.m., with an efficiency of 60 per cent for the hoist and reduction gears. A straight-edge placed at 10 on the *A* scale and 10 on the *B* scale will intersect the *C* scale at point *J*. Connect point *J* with 1,000 on the *D* scale and it will intersect the *E* scale at point *L*. Place the straight-edge on point *L* and 0.6 on the *F* scale and it will intersect the *G* scale at point *N*, which reads 100 hp., for the required motor rating.

In using the chart, note that the scales are lettered consecutively *A* to *G* in the order of their use. First place a straight-edge on the value of the unbalanced weight to be hoisted and on the value of the per cent grade. The intersection of the straight-edge on the pivot scale *C* is noted. Then place a straight-edge on this point of intersection on the *C* scale and the value of hoisting speed used, on the *D* scale, and note the intersection of the straight-edge on the pivot scale *E*. Do likewise with this point of intersection on *E* and the efficiency value required on scale *F* and note the intersection point on the *G* scale. This point on the *G* scale is the value of horsepower necessary for the conditions given. The problem worked out on the chart will illustrate the procedure.

This chart will be found a time saver, as a ready reference and, after a little practice, extremely simple to use. The range of values are so determined that they will meet the usual requirements.

CHARLES F. CAMERON.

Rock Springs, Wyo.



Mechanical maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Selecting Worm Gear Speed Reducers of Proper Capacity

THE gear speed reducer has become a very important factor in the past few years as a menas of stepping down high-speed commercial motors and other prime movers where they are to function with machinery and equipment operating at lower speeds. This same statement applies equally to the spur, worm, and herringbone gear types of speed reducers, all of which have certain uses for which they are best adapted.

The worm gear speed reducer is suitable for use in installations where the direction of the power drive must be changed at right angles. This article will be confined to a discussion of the worm gear speed reducers with particular attention to how these reducers can be applied in meeting individual speed reduction or power transmission problems. Basic information giving formulas and a knowledge of the applications of speed reducers to practical problems is important to the executive or engineer, when he has in mind the use of speed reducers in new equipment, or for replacements. This article follows closely the lines of a previous article (page 96, February, 1926) which described the methods employed in the selection of spur gear speed reducers of proper capacity.

In dealing with worm gear speed reduction problems practically the same information relative to loads, horsepower and torque, is necessary in making the calculations as is required for the spur gear type. It must be remembered that, theoretically, the same horsepower is delivered by the reducing units as is delivered by the prime mover. The speed, however, decreases through the worm reducer, depending upon the reduction ratio used, and the torque or twisting moment correspondingly increases.

It must be borne in mind, also, that worm drives are inherently less efficient than spur gear reducers, and the power delivered to the driven unit will be considerably less than the power received, because of frictional and other losses in the worm drive. Therefore, this factor must be considered in making calculations. The formulas to be used in making computations for spur gear speed reducers and examples of their application were given in the item which appeared on page 96, in the February, 1926, issue of INDUSTRIAL ENGINEER and will not be repeated here. To make a proper selection of the correct size of worm gear reducer to meet a given set of conditions, it is necessary to have a clear understanding of the relation of the various elements involved. Simple formulas show the relation of horsepower, load, and torque, and how to calculate the capacity of worm gear speed reducers required to meet certain conditions. The symbols used in the formulas are as follows:

P = Load in pounds on drum or pulley.
P_1 = Standing load in pounds on worm gear.
$2\pi R$ = Circumference of worm gear (inches).
N = Revolutions per minute (r.p.m.).
T = Torque or twisting moment in inch-pounds.
W = Work done.
$Hp.$ = Horsepower. (33,000 ft.-lb. per min.)

Torque or twisting moment is that force which tends to produce rotation in a shaft or pulley and is equal to the product of the force acting times the length of the lever arm. This is expressed by a formula, $T = P \times R$ (see Fig. 1).

Work done is equal to the product of the force acting on the object, times the distance through which it moves. When D = distance traveled, then $W = P \times D$.

The distance through which the force acts in one revolution is equal to the circumference of the circle, which is $2\pi R$. Work done in one revolution is expressed, $W = P \times 2\pi R$ in.-lb. Where the drum or pulley makes more than one revolution the total work done will be, $W = P \times 2\pi R \times N$ in.-lb.

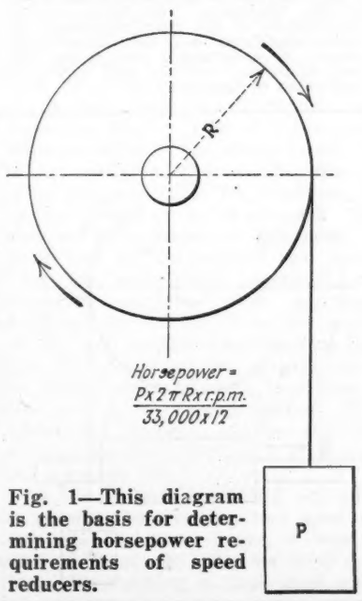


Fig. 1—This diagram is the basis for determining horsepower requirements of speed reducers.

Since 1 hp. is equivalent to 33,000 ft.-lb. per min., the horsepower required to revolve the pulley N times per minute against the weight P will be: $Hp. = (P \times 2\pi R \times N) \div (33{,}000 \times 12)$.

Other useful formulas derived from these equations are as follows:

$Hp. = (T \times N) \div 63{,}025;$
$T = (63{,}025 \times \text{hp.}) \div N;$
$T = P \times R; \quad P = T \div R; \quad R = T \div P;$
$W = 2\pi \times T \times N.$

In dealing with worm drives it is necessary to take into consideration standing and running loads on the gear teeth. By standing load is meant the back pressure on the gear due to the load on the driven unit while at rest. Thus, Fig. 2, by applying the formula for torque it will be found that the torque necessary to move the load on the driven shaft will require a gear with radius R, but the standing load on the gear will make necessary a gear of larger radius, R_1, on such applications as elevator hoist drives, and the like.

To arrive at the proper radius for the worm gear in cases of this kind it is necessary to calculate standing and running loads, as follows: $P_1 = (P \times R) \div R_1$, but $T = P \times R$, then $P_1 = T \div R_1$ and $R_1 = T \div P_1$. Then R_1 will be the radius of the worm gear strong enough to withstand the standing load.

By using one or more of the above formulas it is possible to solve practically any speed reduction problem which may be presented; some of the methods used are indicated in the simple problems which follow. Let it be borne in mind, however, that in actual practice, the efficency of both the reducer and the driven machine must be considered, when selecting reducers of the proper size. Some examples of the practical applications of these formulas on worm gear speed reducer problems may be given as follows:

(1) If we have a drum with a radius of 6 in. and a load of 1,000 lb. to be moved, find the torque necessary to move it.

$T = P \times R = 6 \times 1{,}000 = 6{,}000$ in.-lb. torque.

(2) If the drum is to be driven at 1 r.p.m. how much work will be done during this revolution?

$W = 2\pi \times T \times N = 6.28 \times 6{,}000 \times 1 = 37{,}680$ in.lb.

(3) How much horsepower will be required to drive the above drum at 15 r.p.m.?

$Hp. = (2\pi R \times P \times N) \div (33{,}000 \times 12) = (6.28 \times 1{,}000 \times 15) \div (33{,}000 \times 12) = 1.42$ hp.

(4) If we knew that the torque on the drum shaft was 6,000 in.-lb. and the speed 15 r.p.m., what horsepower would be required to drive it?

$Hp. = (T \times N) \div 63{,}025 = (6{,}000 \times 15) \div 63{,}025 = 1.42$ hp.

(5) If 1.42 hp. is required to drive this drum at 15 r.p.m. what is the torque in inch-pounds on the center of the drum shaft?

$T = (63{,}025 \times \text{hp.}) \div N = (63{,}025 \times 1.42) \div 15 = 6{,}000$ in.-lb.

(6) If the torque or twisting moment at standing load on the drum is 6,000 in.-lb. and radius of the drum is 6 in., what is the load on the drum in pounds?

$P = T \div R = 6{,}000 \div 6 = 1{,}000$ lb.

(7) If the torque on this drum is 6,000 in.-lb. and the load on the drum is 1,000 lb., what is the radius of the drum?

$R = T \div P = 6{,}000 \div 1{,}000 = 6$ in. radius or 12 in. diameter.

(8) If the drum radius is 6 in., the load 1,000 lb. on the drum, and the radius of the worm gear is 8 in., what is the standing load on the worm gear?

$P_1 = (P \times R) \div R_1 = (1{,}000 \times 6) \div 8 = 750$ lb.

(9) If the torque on the drum shaft is 6,000 lb. and the standing load on the worm gear is 750 lb., what must be the radius of the worm gear to withstand the load?

$R_1 = T \div P_1 = 6{,}000 \div 750 = 8$ in. radius or 16 in. diameter.

Let us now assume the conditions for a problem and carry the calculation through to the selection of the proper size and type of worm gear reducer to do the work. Assume that we have an elevator whose efficiency is 95 per cent (i.e., the friction loss in bearings, sheaves, and so on equals 5 per cent). The elevator drum or sheave shaft is 18 in. in diameter and is to be driven by a worm gear speed reducer at a speed of 15 r.p.m. The total load to be lifted is 3,548 lb. Speed of the driving motor is 800 r.p.m. The computations are as follows:

$Hp. = (2\pi R \times P \times N) \div (33{,}000 \times 12) = (6.28 \times 9 \times 3{,}548 \times 15) \div (33{,}000 \times 12) = 7.6$ hp.

As the efficiency of the elevator is 95 per cent, the actual hp. required will be: $7.6 \div 0.95 = 8$ hp.

Assume the average efficiency of the worm gear speed reducer as 70 per cent; therefore, the size of motor required will be 8 hp. $\div$ 0.70 = 11.43 hp. (Size of motor required which also indicates the load on the reducer.) The reduction ration is 800 to 15 or 53.33 to 1.

Manufacturers generally list reducers according to capacities and reduction ratios and with the above information a selection of the proper machine can be easily made. It is necessary, also, to calculate the actual standing load for this particular problem and compare it with the safe standing load listed by the manufacturer, to make sure that the reducer selected will withstand the load. Standing load is determined as follows:

$P_1 = (P \times R) \div R_1 = (3{,}548 \times 9) \div 13.5 = 2{,}365$ lb.

The capacity of the driving unit must always be great enough to compensate for frictional and other losses in the reducing unit and driven unit and to start the load on the driven unit even though the power required while running is much less.

The efficiency of worm gear speed reducers varies considerably, depending upon the following factors, which are listed in the order of their importance:

(*a*) Helix angle of the worm.
(*b*) Pitch line speed of the worm.
(*c*) Materials used in the worm and worm gear.
(*d*) Nature of lubricant used.

(*a*) The curves in the accompanying chart (Fig. 3), clearly show the relation of helix angle to efficiency. To use the above efficiency curves it is first necessary to determine the lead or helix angle, as the figures used across the bottom of the curve, Fig. 3, represent degrees. To obtain lead or helix angle use the following formula.

A = Helix angle; L = Lead in inches.
$P.D.$ = Pitch dia. of worm.
Tan $A = L \div P.D.$

The accompanying table gives values for the tangent in steps varying from 5 to 45 deg. which will assist in locating on the efficiency curve the result arrived at by solving the above formula for various leads and pitch diameters of the worm.

Values of Tan A for Helix Angles

Tan. A	Deg.	Tan. A	Deg.
0.087	5	0.577	30
0.176	10	0.700	35
0.267	15	0.839	40
0.363	20	1.000	45
0.466	25		

In cases where worm reduction units are operated under heavy loads at comparatively slow speeds the efficiencies will be considerably lower than indicated by the curve. In such cases the efficiency may be increased somewhat by using a heavy grade of lubricant which prevents the oil film from squeezing out and breaking down.

(*b*) The factor of the pitch-line speed of the worm should be considered in selecting worm reducers, and motors to operate them. Pitch-line speed of worm should preferably stay below 1,000 f.p.m.

(*c*) Long experience and numerous tests by reducer manufacturers have indicated that the combination of a steel worm and bronze worm gear give good results and high efficiency for continuous service. For intermittent service, the steel worm and semi-steel worm gear have been found very satisfactory.

(*d*) The influence of the lubricant used on the efficiency is a minor factor, but the highest efficiencies will be maintained by following the recommendations of the manufacturer for lubrication of a given unit.

For certain classes of work such as hoists, inclined conveyors, or where the load must be suspended after the power has been shut off, it is desirable to have worm gear speed reducers which are self-locking, to prevent a reversal of the reducer. Where such reducers are required a worm with a smaller lead is necessary. Such a worm may be calculated as follows:

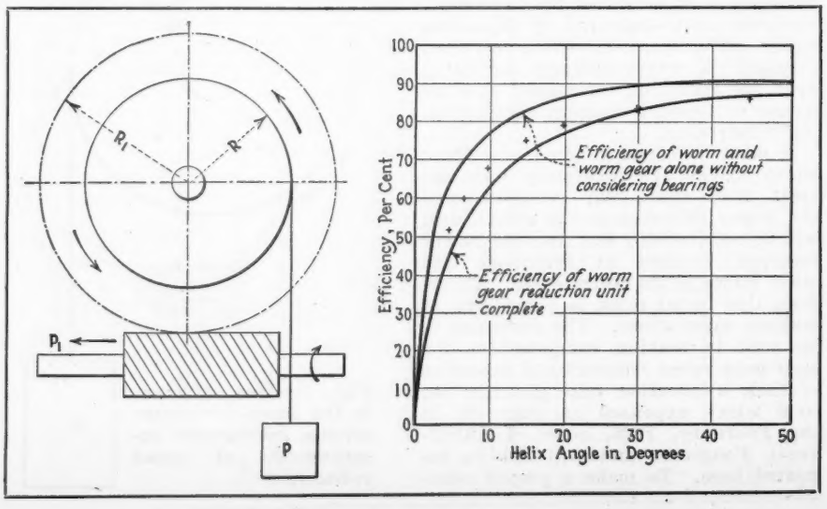
PD = Pitch diameter of the worm gear in inches.
C = Center distance between shafts of worm and worm gear.
P_1D_1 = Pitch diameter of worm.
H = Cotangent of helix angle of worm.
E = Lead in inches of worm thread.

$P_1D_1 = 2C - PD.$
$H = (\pi \times P_1D_1) \div E.$

For a single-thread worm the lead E equals the distance between threads; for multiple worms, multiply this distance by the number of separate

Figs. 2 and 3—Force diagram of worm reducer and worm gear efficiency curves.

The drawing at the left indicates the action of the load on a worm gear and is used in connection with the formulas. The chart at the right shows the relation of the helix angle of the worm to the efficiency. The figures across the bottom of the chart represent the helix angle in degrees. This helix angle is determined by using the accompanying formula and table, as described in the text.



threads. If the angle whose cotangent is equal to H is less than 5 deg. the worm will be self-locking.

Chief Engineer, HARRY C. PETERSON.
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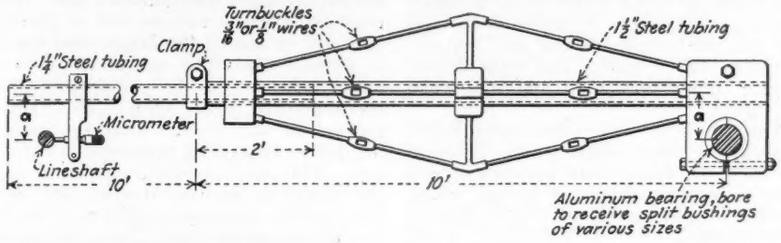
Chicago, Ill.

Method of Checking Parallel Alignment of Machines With the Lineshaft

RECENTLY, I had occasion in connection with the installation of a battery of broad drop hammers, each driven by two belts from pulleys at each end of the hammer shaft, to devise some method whereby the alignment of the shafts of the hammer could be made absolutely parallel with the lineshaft.



This device was used to check the distance between the ends of the shafts of broad drop hammers with the lineshaft, to secure perfect alignment.

The bearing at the right is bushed to fit the shaft of the broad drop hammer. The distance to the lineshaft is then measured exactly by the micrometer. The equipment is then moved to the other end of the shaft and the operation repeated. The difference in the micrometer readings shows how much the shafts are out of alignment.

To do this the special gage shown in the accompanying sketch was constructed. This consists primarily of a brace and two pieces of steel tubing, one of which will slide inside the other but still has a close enough fit so that it will not allow any side motion. A clamp permits fastening the two tubes together in any position.

The piece of 1½-in. tubing is 10 ft. long and the piece of 1¼-in. steel tubing, which fits inside of it, is 12 ft. long. There should be a minimum of 2 ft. overlap of the two tubes. When extended to full length, this device may be used to check the alignment of shafts about 20 ft. apart, or it may be shortened up to about 10½ ft. as a minimum distance. These lengths may, of course, be made to fit any special conditions although probably the length indicated above would be the maximum for convenience in handling.

The brace consist of three aluminum castings and four wires or braces with turnbuckles in them. The four-armed spider in the center of the brace may be made either from an aluminum casting, or built up by welding. The ends of the brace were made from aluminum castings, as shown. The large casting at the right is made to clamp around the piece of 1½-in. steel tubing; the bearing which is at right-angles to the steel tubing is bored out to a larger diameter than any of the shafts on the broad drop hammers. Hammer shafts of different diameters were taken care of by using various sizes of split bushings. When in use this bearing is clamped onto one end of the shaft of the hammer.

The casting on the other end of the device holds an inside micrometer, as shown, and is moved along on the tubing until close to the lineshaft and then clamped. It is then possible to make a careful adjustment and measurement of this distance. Additional adjustments for distance may be made by loosening the clamp in the center and sliding the 1¼-in. tubing in the larger tubing.

After taking measurements at one end, the device is then moved to the other end of the hammer shaft and the operation repeated. The difference in the readings of the micrometer shows the amount that the shafts are out of alignment. After the machine is straightened around, the alignment is again checked in the same way. This is repeated until there is no change in the micrometer readings.

Mechanical Engineer, W. W. NICHOLS.
D. P. Brown & Co.,
Detroit, Mich.

Selection of Gears and Pinions for Steel Mill Service

WE HAVE experimented with gears and pinions on cranes and mill motors for a long time. Several different manufacturers' products have been used, many of which have given excellent results. For several years our experiments were confined to pinions which revolved at high speeds, and consequently wore out most frequently. We felt that a worth-while saving could be made, if a satisfactory gear material could be found. About 20 years ago we purchased three so-called tool steel pinions made by the Tool Steel Gear and Pinion Co., Cincinnati, Ohio. These pinions had 14 teeth, 3 diametral pitch, 5-in. face, 2½-in. tapered bore for use on a No. 38-B Westinghouse motor armature shaft. Two of these pinions were installed on the motor drive of the bridge motion of the tilting tables of a structural mill, and the third was used on the ram of an ingot stripper. These pinions were inspected frequently for wear and at the end of six months, when no wear was apparent, more armature pinions were purchased. Although the record of the two pinions on the mill tables was lost, we know that the pinion on the stripper lasted six years, which is about ten times the life of a hard, forged pinion. From subsequent records of the tool steel products we find that this is a conservative average life.

As the manufacturer did not advise or recommend running tool steel pinions into tool steel gears, it was not until 12 years ago, that we tried doing this. By running a tool steel pinion in mesh with the tool steel gear, we get still more service and reap the benefit of longer life of our large motor gears on our many important cranes and machines. Such excellent results were obtained from our motor gears and pinions that for the past ten years we have been using tool steel pinions almost exclusively on the trolleys and bridges of 150 cranes.

We have used certain special, heat-treated gears, also rolled-steel gears, and have found them to give much better service than cast-steel gears. We have tried a special hardening process on cast-tooth gears, cast in our (and other) foundries, but very poor results were obtained. This was probably due to lack of knowledge of how to correctly heat-treat the gears. The hardening was not altogether confined to the teeth, as intended, but got over the shrouds and the ends where it made machining impossible. Quite a number of castings were scrapped on this account. One 14-tooth, 7½-in. face pinion, which was installed on a stripper, ruined the teeth of the rack in a few days. The cause of this was hard, flinty, sharp spots on the teeth, the first evidence of which had been removed by grinding before the pinion was received. This, with the installation of two 17-tooth, 2-in. circular pitch pinions on an open hearth furnace charging machine, which ruined the gear in a short time, ended our experiments with that special hardening of cast-tooth gears.

On constant-speed motors we use common forged steel, tool steel, rawhide, Fabroid, and Bakelite Micarta pinions. Where steel pinions must be used on account of heavy pulls and sudden shocks, tool steel is far superior and more economical than forged steel. Rawhide pinions are very good, and are noiseless, but have a higher initial cost and unless the spares are kept in a damp place they shrink very rapidly in diameter and loosen up in the rivets. A Bakelite Micarta pinion on a gear cutter in the electric machine shop has been in use for seven years and shows very little wear. A steel pinion on this application did not last a year and in addition was very noisy.

Common, open-hearth cast-steel gears can be heated and shrunk onto shafts, giving a very tight fit for hard service, or they can be driven or pushed into place. Tool steel cannot be driven without injury, as the teeth of the pinions will be fractured and the webs of the gears may be cracked. As it cannot be heated except in boiling water, all tool steel pinions are ordered "push fit." No extra care in lubrication is required.

Rawhide pinions require perfect fitting on the shaft and key and are hard to remove after they have been in service for some time. Nothing should be used for their lubrication except a light coat of melted tallow occasionally. Fabroid absorbs oil which may get on it from adjacent gearing or due to carelessness in oiling. Nothing should be used for lubrication of this type of pinion except dry graphite which should be rubbed on the teeth only infrequently, when required.

D. W. BLAKESLEE.
Electrical Engineer,
Jones & Laughlin Steel Corp.
Pittsburgh, Pa.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contributions are always welcome.

Changing Phase and Voltage of Turbo-Generator

A LARGE industrial concern bought from a second-hand dealer a turbo-generator whose rating at the a.c. end was supposed to be 625 kva. 230 volts, 60 cycles, three phase. However, when this machine was connected to the line it would not deliver its full rating and would become hot in spots. The manufacturer of the machine was consulted and it was learned that the generator was originally rated at 625 kva., 450 volts, 60 cycles, two phase. The winding had 48 slots, 24 coils, one coil side per slot, being of the bar-and-end-connection type, back pitch 1-and-14, front pitch 1-and-12.

What the dealer had done to make it a three-phase machine was to cut out six coil bars and connect the machine two-parallel star. Eliminating the six bars or three coils caused heating and left 21 active coils in the machine or $21 \div 3 = 7$ coils per phase. As this was a two-pole machine there were two groups per phase and the dealer had put three coils in one group and four in the next and then paralleled the two groups, which resulted in an unbalanced condition, setting up circulating currents. To obtain proper results the six coil bars were put back into service and the following alterations made. The coil pitch was changed to 1-and-12, rear, and 1-and-10, front, the same end connection being used by springing them together for the shorter throw.

The reasoning involved was as follows: For the two-phase, 450-volt winding, the pitch was 1-and-14; then the voltage per phase for three phase equals $(450 \times 2 \div 3) \times (0.955 \div 0.905) = 316.56$ volts for the line voltage of a series-delta connection. But only 230 volts are required. If the stator were connected series-star the line voltage would be $316.56 \times 1.73 = 547.65$ volts and a two-parallel star connection would reduce the voltage to $547.65 \div 2 = 273.83$ which would still be too high and the chord factor would have to be reduced in this case to $230 \div 273 = 0.843$. The span is 180 deg.; full pitch equals 48 slots $\div$ 2 poles = 24 and the chord factor at full pitch or 24 equals 100 per cent which is also the sine of one-half the angle covered by the coil throw. Span at full pitch equals $180 \div 24 = 7.5$ deg. per slot and for a throw of 1-and-14 it would be 13×7.5 or 97.5 deg. The sine of one-half of 97.5 deg. = 0.7509 or the chord factor at 1-and-14. The 230-volt factor must equal $0.7509 \times 0.843 = 0.6330$ which is the sine of 39.3 deg., or the coil throw angle equals 78.6 deg., and the coil pitch equals $78.6 \div 7.5 = 10.5$ slots. Now, when there is only one bar per slot the pitch has to be odd; that is, 1-and-12, 1-and-14, and so on. The 1-and-10 pitch would be too short and the 1-and-12 pitch would give a chord factor of 0.66; this is $0.66 \div 0.75 = 88$ per cent reduction, or the line voltage would be $273 \times 0.88 = 240$ volts, which is only 4 per cent high and will work all right.

The machine was then reconnected two-parallel star, pitch 1-and-12, using all 24 coils, eight coils per phase and four coils per pole-phase group, which worked satisfactorily. A. C. ROE.
Wilkinsburg, Pa.

How to Make a Soldering Iron Heated by a Carbon Arc

BOTH industrial and commercial electric repair shops have a large amount of soldering to do.

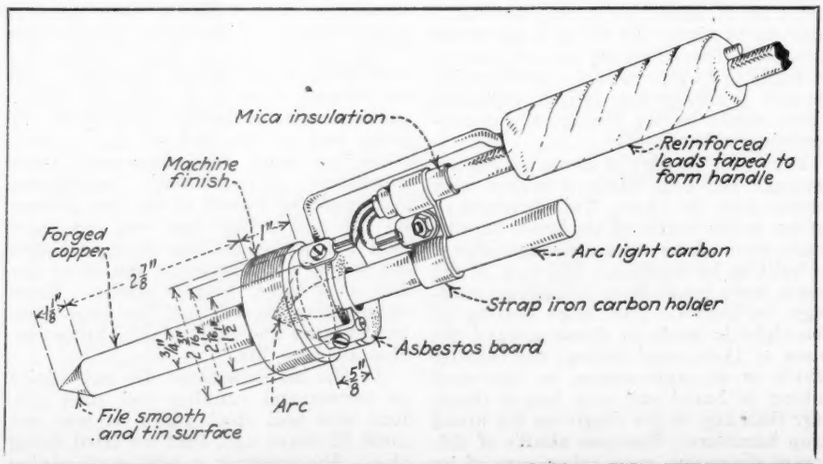
Under these conditions the use of the ordinary soldering iron heated in a furnace or fire pot is rather costly and not altogether satisfactory, as time is lost in waiting for the irons to heat and frequent filing and tinning are necessary. Also, inasmuch as the irons cool off rapidly it is sometimes difficult to obtain a smooth soldering job, so that filing or scraping may be required.

On the other hand, some types of electric soldering irons will not stand continuous operation when kept hot enough to do any volume of work.

The soldering iron shown in the accompanying illustration has been used with good success for a number of years in one of the large steel works in Pittsburgh. The use made of it is mainly for soldering commutators in the armature repair shop. An unusual feature of this iron is that the soldering bit is heated by means of a carbon arc. This arc is held between a carbon electrode and the copper bit itself. The carbon electrode is held in a handle in such a manner that it may be moved forward gradually as it is burned up. The soldering iron requires about 2½ amp. and is fed from a 230-volt, direct-current supply using enough resistance in series with it to hold the current at the value given. The cost of operation to the user when employed in a large industrial works, will be found to be almost nothing.

The soldering bit is made of forged copper and is machined and drilled according to the dimensions shown on the accompanying sketch. It will be noticed that there are three ⅛-in. holes drilled in the rear end of the bit. These are tapped for machine screws. One lead from the power supply is fastened to the bit by means of a machine screw, as is shown in the illustration. A metal support made of strap iron and bent to form a handle is fastened to the copper bit by means of one of the other machine screws. The third machine screw is used for attaching a small strap iron clamp to which is fastened an asbestos board screen which encloses the hollow end of the copper bit so that the eyes of the operator will be shielded from the arc while it is in use.

This soldering iron will stand continuous service and may be operated at an almost negligible cost. It is connected in series with resistance to the 230-volt d.c. power supply and requires a current of 2½ amp. The only materials required to make this iron are a forged copper bit, a ½-in. arc carbon, a few pieces of strap iron, some copper wire leads and an asbestos board screen.



One end of a strap iron clamp is attached to the lead connected to the copper bit and the other end of the clamp holds the carbon electrode in the center of the bit, as shown. The second lead from the supply is attached to the strap iron clip. This clip is insulated from the first lead by means of mica insulation. The asbestos board screen has a hole drilled through it that fits around the carbon very loosely so that the latter may be gradually pushed forward as it is consumed by the arc. The two leads, together with the strap iron handle are all taped together so as to make a handle having sufficient strength and balance to give convenient operation. The carbon electrode is an ordinary ½-in. arc carbon and is held in the clip with only enough friction to prevent any movement while using the iron and yet permit a forward movement of the carbon when the iron is jarred slightly.

Electrical Engineer, D. W. BLAKESLEE.
Jones & Laughlin Steel Corp.
Pittsburgh, Pa.

How to Make Inexpensive Lathe for Banding Armatures

WHEN banding armatures it is common practice in repair shops to use a special banding lathe, or an ordinary lathe with special attachments. However, special armature-banding lathes are rather expensive for shops that do not have to band many armatures, while some of the makeshift devices that are sometimes used do not turn out a satisfactory job.

The illustration shows a very satisfactory banding lathe that was made from an old worm-gear reduction, some structural steel shapes, and a few machined parts. This lathe has an overall length of 7 ft. 11⅛ in., height 3 ft. 10½ in., and width 2 ft. ¾ in. The center line of the armature to be banded was fixed at 3 ft. 2 in. from the floor level. This height seems to give about the right working distance for any armature that the machine will handle. The machine will accommodate an armature whose shaft length does not exceed 5 ft. 8 in. or whose maximum diameter does not exceed 27 in. The armature should not weigh over 1,500 lb., although if the tail stock is kept close to either of the legs, a weight of 500 lb. extra may be safely handled.

Parts *B*, *C* and *D*, the legs, were made from 2½-in. by 2½-in. by ⅜-in. angles. Parts *E*, *F*, *G* and *H*, the horizontal supports for the tail stock and worm-gear reduction, were made from 2½-in. by 3½-in. by ⅜-in. angle iron.

The braces *L* and *M* at the bottom may be made from any small angle iron, such as 1½-in. by 1½-in. by ⅛-in., as they do not bear any of the weight of the machine. The two longer legs, *B* and *C*, were made 2 ft. long while the length of the two shorter legs is governed by the height of the gear reduction, as it is necessary to keep the center of the driveshaft on the gear reduction at the same height as the center of the tailstock screw. The ⅜-in. gusset plates shown as part *A* on the sketch are 6 in. by 6 in., and were cut to fit the angles used. The legs of the angles *B* and *C* were turned in and the gusset plates placed between them and the horizontal members. The construction at the corners may be seen from the sketch. It will also be noted that the longer leg of the horizontal members is used vertically, so as to secure the greatest stiffness.

The tailstock consists of six different pieces, exclusive of nuts, bolts and lockwashers. The sliding support *J* consists of an 8-in., 18¾-lb. channel iron, drilled so that it may be bolted at various distances from the gear reduction, to allow for variation in armature shaft length. Upon it are bolted two L-shaped pieces, *T*, made of ¾-in. by 6-in. steel bar. Block *P*, which carries the tailstock screw, is a block of steel 4 in. by 4 in. by 6 in. tapped for a 1½-in. standard machine bolt. It is also drilled and tapped for bolting to the two L-shaped pieces, *T*, which are in turn bolted to the sliding, channel-iron base. The tailstock screw itself is a 1½-in. machine-bolt, 12 in. long tapered to a center point at one end and hardened. It is also equipped with a crank or handwheel for turning. It is necessary to have a setscrew, *O*, in the tailstock block, and this should be tightened whenever the machine is in use; otherwise the tailstock screw may turn when the machine is running which would either bend the armature shaft or wreck the machine.

A channel, bolted between the two cross-members, supports one side of the worm-gear reduction while the other side is supported by the table angle. The channel may also form a support for one side of the motor base.

All angles and other parts were bolted together, lockwashers being used in all cases. Holes should be drilled ⅛ in. oversize unless unusual care is used in laying them out. Riveted construction is, of course, to be preferred, but bolted construction will give satisfactory results, provided the nuts are turned up tightly. The use of ½-in. machine bolts is recommended for the construction of the framework, while in the tailstock assembly ⅝-in. bolts may be used.

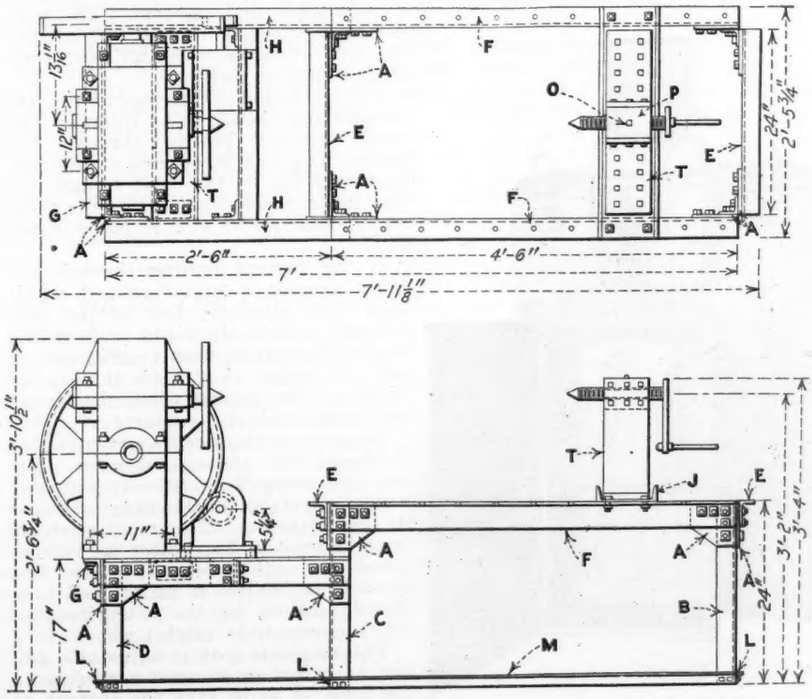
The driveshaft on the gear reduction was turned down at one end and hardened. A keyway was also cut in the tapered end of this shaft, and a slotted faceplate such as is used on a lathe was keyed to it. When banding an armature a lathe dog is fastened to the shaft, the other end of the dog engaging in the slot in the faceplate. A ¾-hp. 1,760-r.p.m., d.c. motor is used on this machine, the speed being cut down by the gear reduction from 1,760 r.p.m. to about 4 r.p.m. A double-pole, double throw, knife switch and starting rheostat were mounted on the machine by means of brackets. It is important that the starting rheostat and knife switch be placed within easy reach of the operator. All moving parts such as gears or live electrical parts should be guarded so that injury to the operator is impossible.

At the present time the banding wire is placed on a reel near the machine and tension is secured by running the wire through two pieces of fiber clamped upon a horizontal member of the machine at the point where the banding is to be done. In winding brake coils or other coils in which insulated wire is used, the wire reel is placed a short distance behind the machine on a rack. The desired tension is secured by hanging a steel wire with weights on each end in the grooves on the reel. The tension may be changed by varying the weights.

The advantages of this lathe are low cost and greater durability and utility than are found in ordinary makeshifts.

Toronto, Ohio. HERBERT KING.

This armature-banding lathe was made from an old worm gear reduction, structural steel shapes and a few machined parts.



New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Covered Plug Fuse Cutouts

IN ORDER to meet the demand of various localities which now require the use of dead-front cutouts in place of the old style, in which the terminals are exposed, the Trumbull Electric Mfg. Co., Plainville, Conn., is listing a new two- and four-circuit, covered cutout to meet these requirements. The former is shown in the accompanying illustration. Covers for these cutouts are made of steel,

which are backed by an insulating plate with test holes, which permit testing without removing the covers. The test holes are well insulated and in plain sight. The cutouts may be wired for single fusing with two- or three-wire mains, or for double fusing with two-wire mains. It is stated that the screws cannot fall out when the covers are removed for wiring and when the units are arranged in gangs, the screws hold the covers together, which insures pressure connections for grounding purposes. The grooves shown in the side are for the meter connections. The connection to ground is easily determined by location and color. Because the covers extend over the contact terminals, which are recessed in the porcelain, it is claimed that no barriers are required. This type of cutout is made in the 30-amp., 125-volt size.

Elevating Platform Truck

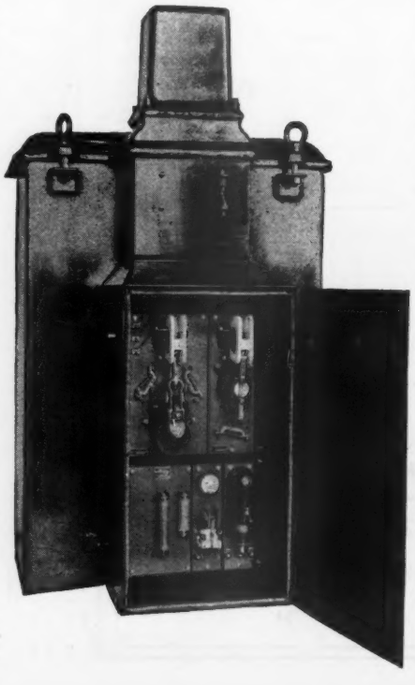
ANNOUNCEMENT is made of a new elevating platform truck, designated as the Yale K 23 E, by the Yale & Towne Manufacturing Co., Stamford, Conn. This truck is designed primarily for heavy loads. Although this machine is not of the high-lift type, such as the Yale K 22, it does embody the self-loading feature. The short turning radius and the narrow width of this machine are said to make it easy to drive in and out of box cars or narrow aisles. Hardened steel steering pivots with bronze bushings and the high-pressure lubricating system reduce friction and make steering easy, it is stated, even when carrying a full load.

The triple spur-gear elevating mechanism consists essentially of the same unit as is used in the K 22 truck, making the major replacement parts interchangeable between models. The elevating platform is raised by means of two large eccentrics mounted on the hoist unit shaft, which draw the platform forward and upward on the platform links. The majority of parts, units and sub-assemblies of this truck are standard and interchangeable with those of all other models in the K series manufactured by the company.

Synchronous Motor Control

DEVELOPMENT of a completely self-contained, oil-immersed automatic starter for 2,300-volt synchronous motors has been announced by the Electric Controller & Manufacturing Co., Cleveland, Ohio. This unit is built for across-the-line starting of slow-speed motors, and for reduced voltage starting of the higher-speed motors. The illustration shows a reduced-voltage type starter. The full-voltage equipment for starting slow-speed motors is of similar appearance except that the height is reduced. It is stated that in each case the operator simply pushes a button to start the motor and as the motor approaches synchronous speed, the field excitation is automatically applied.

According to the manufacturer's description, the reduced-voltage starter consists of a welded boiler-plate tank which contains an automatic, double-throw switching mechanism, a power transformer for providing starting voltage, potential transformers for providing 220 volts for operating the master switch and the current-limit transition relay, which connects the motor to full voltage when it has been accelerated to about 85 per cent of synchronous speed.

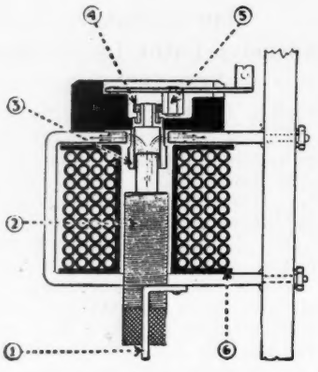


A dustproof steel cabinet on the outside of the tank encloses a field switching mechanism, field discharge resistor, timing relay and d.c. field ammeter. This cabinet may also contain an automatic starter for operating a magnetic clutch. The full-voltage starter is of similar construction except that the starting auto-transformers are omitted.

This equipment is said to be complete in a single unit and makes possible floor-mounting of all equipment required for starting synchronous motors.

Thermal Relay

THE "Inducto-therm" relay, which can be adapted to a wide range of horsepowers without changing the thermal element, has been placed on the market by the Allen-Bradley Co., 286 Greenfield Ave., Milwaukee, Wis. The company is using this relay as the protective unit on some of its standard a.c. switches and starters. The type J-1552 across-the-line starting switches are now available with this new relay incorporated in them.



The operation, referring to the accompanying sketch, is as follows: The motor current flowing through the magnetizing coil, *6*, creates a pulsating magnetic flux in the core, *2*, and this flux induces eddy currents in the thermal element shown at *3*, by transformer action.

If the current flowing through the relay exceeds a predetermined maximum, the magnetic flux in the core becomes sufficiently dense to heat the copper thermal element *3* sufficiently to melt the solder which holds the ratchet wheel *4*. The ratchet wheel then turns and opens the relay contacts.

As soon as the motor current is interrupted the thermal element cools and the solder automatically sets and holds the ratchet wheel ready to repeat its performance. The relay contacts must be reset by hand after the ratchet wheel has again become fixed. The contact mechanism is maintained in a closed position by the reset lever *5*, which engages the ratchet wheel.

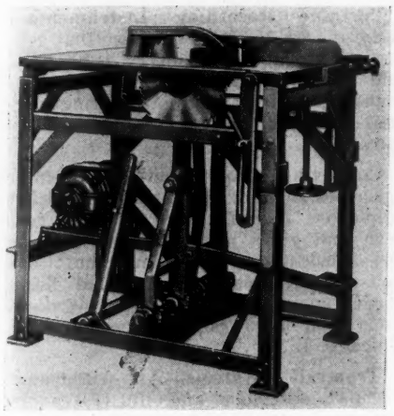
The magnetic core is adjustable and can be raised or lowered according to the scale so as to vary the current at

which the relay will trip. The relay can be adjusted over a range of from 1 hp. to 5 hp. for a given voltage, and all intermediate horsepower ratings can be obtained without changing the thermal element. The same type of relay can be used on larger horsepower ratings of controllers with the same degree of flexibility.

Portable Saw Table

MARKETING of the Wonder portable saw table for use with either cut-off or rip saws is announced by the St. Louis Machine Tool Company, 1429 Pine St., St. Louis, Mo.

The portable saw unit that is shown



in the accompanying illustration is operated by a 1-hp., ball-bearing, 1,750-r.p.m. motor. This motor is of the semi-enclosed type and can be furnished for operation on either direct current or single-phase alternating current at 110, 220, or 440 volts, 60 cycles. If desired, a 1-hp., 1,750-r.p.m., 1-cylinder, 4-cycle gasoline engine may be supplied in place of the motor.

The table top is made of cast iron, while the frame is constructed of angle irons bolted together. The motor or gasoline engine is bolted to a jackshaft which, in turn, is belted to the saw through an idler pulley. The entire saw unit is pivoted at the base around the center line of the jackshaft and by means of a foot-controlled lever the saw is swung through an arc and thus advanced through the work which is held stationary.

Brass Cups for Traffic Markers

MARKERS for aisles and traffic lanes in industrial plants, as well as for street service, have been developed recently by the Bridgeport Brass Co., Bridgeport, Conn. These consist of round brass cups which are driven into the floor or pavement or set into new floors and pavements. These traffic markers are made in two diameters, 3 in. for pedestrian markings and 4½ in. in diameter for heavy traffic lines. The manufacturer states that these are highly visible, easily inserted and require no upkeep. They may be inserted in asphalt, macadam, wood block, Amasite, Warrentite, new concrete work and other similar materials.

Primary Resistor Starter

REVERSING primary resistor starters for squirrel-cage induction motors have been announced by the General Electric Co., Schenectady, N. Y. Two three-pole line contactors are provided with this starter, which is designated by the style number CR-7055-A-1.

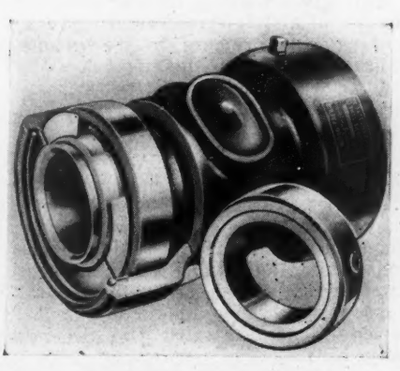
These contactors are electrically and mechanically interlocked and are mounted back-to-back on the panel. A magnetic time interlock provides a predetermined definite time of from one to three seconds between the closing of the line contactor and the accelerating contactor.

Two-point starting is provided by a resistor designed to confirm to Electric Power Club classification No. 16. A temperature overload relay with an external resetting mechanism furnishes overload protection. The inclosing case is of sheet metal, semi-ventilated, and is provided with feet for wall mounting. When mounted, the panel occupies a position at right angles to the wall. Doors are provided at back and front.

Ball-Bearing Hanger Box

ADOPTION of the Fafnir bearing as an incorporated part of its own line of transmission equipment has been officially announced by the T. B. Wood's Sons Co., Chambersburg, Pa. Fafnir ball bearings have been used in "U.G." hanger boxes, Wood's loose pulleys and friction clutches for many years, but they are now adopted as a standard part of the entire Wood line of power transmission equipment. The most recent addition has been the Wood-Fafnir hanger box which is shown in the accompanying illustration. The housings are made in several styles with bosses designed to suit the different types of hanger frames that are of standard manufacture.

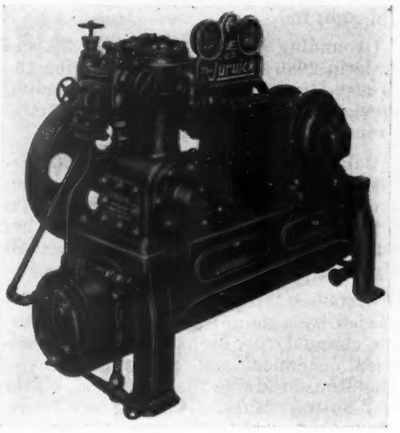
The manufacturer states that plain or babbitted bearing boxes can be replaced without removing the present hanger frames and that the Wood-Fafnir ball-bearing hanger box needs no adjustment when mounting on the shaft as it is necessary simply to slide the box and the two locking collars to place on the shaft and into the frame, then draw up the frame bolts and tighten the collars. It is also stated that the hanger box is dustproof and leakproof. Lubricant is supplied through two tapped holes which are fitted with standard pipe plugs and, according to the manufacturer, lubrication is generally necessary only twice a year.



It is the purpose of this company to make not only ball-bearing hanger boxes, but also ball-bearing post hangers, pillow blocks, loose pulleys, and friction clutches: in fact, a complete line of ball-bearing-equipped transmission machinery.

Automatic Refrigerating Unit

THE American Engineering Co., Philadelphia, Pa., announce an improved, self-contained, automatic, 2-ton refrigerating unit as an addition to the Juruick line. This unit, which is shown



in the accompanying illustration, is especially designed for automatic operation and includes a motor, compressor, condenser, and ammonia storage tank compactly mounted on one base and provided with all necessary controls. A 3- to 5-hp. motor is provided, according to conditions. This unit may be used for factory lunch rooms, circulating water systems, or other industrial applications within its capacity.

Light-Weight Welding Torch

FOR work not requiring the usual standard torch, The Alexander Milburn Co., Baltimore, Md., has perfected a small, type J-Jr., light-weight welding torch. This is said to be a sturdy, compact torch giving a high degree of efficiency and economy. The torch uses the same tips as are supplied with the standard larger torches and, according to the manufacturer, is adaptable to all classes of welding. It uses low and approximately equal pressures of oxygen and acetylene.

The J-Jr. torch is adapted to gas supplied either from generators or compressed in tanks. The torch is made of bronze forgings and drawn stainless tubing. It is said to be simple in construction, with all parts easily accessible and the head set at an angle of 67½ deg.

The manufacturer states that this torch is well balanced, is easily manipulated and will not tire the operator. The J-Jr. is 18 in. long, weighs 25 oz., and is furnished with three welding tips adaptable to a wide range of welding.

Trade Literature
you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Tape—A number of circulars describe each of the various types of tape for different uses put out by this company. —The Okonite Co., Inc., Passaic, N. J.

Water Softener—Bulletin 509 illustrates and describes the Graver Zeolite water softener.—Graver Corp., East Chicago, Ind.

Grounding Condulets—Folder 39 and bulletin 2089 illustrate and describe the Crouse-Hinds condulets for grounding service wires in conduit systems.—Crouse-Hinds Co., Syracuse, N. Y.

Balancing Device—Treatise No. 2 discusses the Gisholt method of balancing armature shafts, pulleys, crankshafts for gas engines and numerous other high-speed rotating parts.—Gisholt Machine Co., Madison, Wis.

Slate—A circular, which is accompanied by a sample, discusses the merits claimed for Monson slate in electrical, chemical and structural uses.—The Monson Maine Slate Co., 112 Water St., Boston, Mass.

Fire Extinguishers—A circular describes the Rego Fire Stopper which is a portable, non-liquid fire extinguisher said to be particularly adapted for protection against fires in oils and flammable liquids.—The Bastian-Blessing Co., Chicago, Ill.

Acetylene Generator—A circular announces a reduction in prices on all sizes of Smith's automatic acetylene generators in portable and stationary types.—Smith Welding Equipment Corp., 2633 4th St., S. E., Minneapolis, Minn.

Welding Rods—A 24-page booklet entitled, "Effect of Surface Materials on Steel Welding Rods," stresses the advantages of Weldite welding rods for gas and electric welding.—Chicago Steel & Wire Co., 103d St. and Torrence Ave., Chicago, Ill.

Motor Control—A series of bulletins entitled "Mill Motor Gossip" describes in an interesting manner the lines of new equipment brought out by this company and the work they will do. The description is brought out in an imaginary conversation carried on between the various mill motors.—The Clarke Controller Co., 1146 E. 152d St., Cleveland, Ohio.

Static Condensers—Leaflet 20,286 discusses the application, construction and installation features of static condensers for power factor correction on motor circuits of 220, 440 and 550 volts. A table gives the corrective kva. for various ratings of three-phase, 60-cycle, type, CS squirrel-cage induction motors ranging from ½ to 200 hp.—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Watt-Hour Meters—Bulletin 71 contains instructions for the installation, operation and maintenance of the Sangamo type D-5 watt-hour meter.—Sangamo Electric Co., Springfield, Ill.

Centrifugal Oil Purifier—A six-page circular describes the De Laval method of purifying transformer and switch oil.—The De Laval Separator Co., 165 Broadway, New York, N. Y.

Car Spotter—A circular describes the Caldwell vertical-capstan car spotter which is made in two sizes operated by 5-hp. and 10-hp. motors and with capacities up to three or six cars respectively.—H. W. Caldwell & Son Co., 1700 S. Western Ave., Chicago, Ill.

Compression Clutch—Bulletin 35 describes the Conway compression clutch which is made as a clutch, clutch coupling and clutch pulley for transmission work as well as for machine application.—The Conway Clutch Co., 1935 W. Sixth St., Cincinnati, Ohio.

Conveyors—A circular describes the Stearns carriers, idler pulleys, and return rollers for belt conveyors and their methods of lubrication, as well as the Holotile storage bin for coal and other loose material.—The Stearns Conveyor Co., E. 200th St. and St. Claire Ave., Cleveland, Ohio.

Graphic Meter—Bulletin 525 describes and illustrates the equipment, operation and application of the Esterline-Angus quick-trip graphic meter which speeds up the drive automatically whenever trouble occurs and automatically returns to normal speed at the end of the disturbance.—The Esterline-Angus Co., Indianapolis, Ind.

Wire Rope—The May issue of "The Yellow Strand," a monthly house organ, celebrates the occasion of the 50th anniversary of this company, giving its history, a description of the plant and numerous illustrations of applications of Yellow Strand wire rope.—Broderick & Bascom Rope Co., 801-809 N. First St., St. Louis, Mo.

Refractory Gun—A circular describes the use of a Quigley refractory gun for making quick repairs in the maintenance of furnace linings, as well as for industrial plastering and stuccoing.—Quigley Furnace Specialties Co., Inc., 26 Cortlandt St., New York, N. Y.

Motors — Circular GEA-6 describes the G.E. squirrel-cage motors of the 500 series. Circular GEA-71 describes the types MT and MQ wound-rotor induction motors of the 900 series for constant or adjustable varying speed. Circular GEA-246 describes the general-purpose synchronous motor of the 7500 series.—General Electric Co., Schenectady, N. Y.

Diesel Engine—Bulletin 707 describes the Foos type L Diesel engine units which are made with two to eight cylinders, with a power range of 50 to 475 hp., and in speeds up to 900 r.p.m.—The Foos Gas Engine Co., Springfield, Ohio.

Magnetic Brake—Bulletin 102 describes the Clark Three-C magnetic brake for use with series or shunt-wound direct-current motors on cranes and similar applications.—The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

Oil Engine—A 32-page catalog illustrates and describes the application, construction and operation of the Ingersoll-Rand type PO direct-ignition oil engine—Ingersoll Rand Co., 11 Broadway, New York, N. Y.

Portable Recording Instruments—Bulletin GEA-304 describes the construction and operation of type CP-4 and CP-5 portable recording instruments for direct and alternating current.—General Electric Co., Schenectady, N. Y.

Conveying Equipment—A circular describes some of the screw and bucket conveyors manufactured by this concern and gives particular attention to the lubricated gear countershaft box end for helicoid and sectional flight screw conveyors.—H. W. Caldwell & Sons Co., 1700 South Western Ave., Chicago, Ill.

Tramrail Systems—An eight-page circular describes and illustrates the use of Cleveland hand and electric tramrail systems for handling waste paper in bales in storage and in paper mills. Another circular describes applications of similar equipment in rubber mills.—The Cleveland Electric Tramrail Division of The Cleveland Crane & Engineering Co., Wickliffe, Ohio.

Portable Power Shear—A circular describes the Unishear which is a motor-operated, portable shear for cutting flat sheets up to 14 gage steel and 12 gage soft metal at a speed of 15 f.p.m. This shear may be used on either straight or irregular cutting of gaskets of any material, as well as sheet metal for guards or ducts.—The Unishear Co., Inc., 170 5th Ave., New York, N. Y.

Pneumatic Tools—Catalog 15 describes the complete line of Thor pneumatic drills, hammers, chisels, hoists and other tools, together with instructions for their maintenance.—Independent Pneumatic Tool Co., 600 W. Jackson Blvd., Chicago, Ill.

Inserts—A circular describes a type of Truscon insert for placing in concrete forms before pouring, to provide a means of attaching fixtures, such as sprinkler systems, plumbing and heating equipment, and suspending shaft-hangers, tramrails and other equipment from the ceiling.—Truscon Steel Co., Youngstown, Ohio.

Fuswitches and Disconnecting Switches—Bulletin 501 gives a complete description of the Matthews equipment in various ratings, discusses safety factor, rupturing capacity, flashover, construction, and other important details. —W. N. Matthews Corp., 3718 Forest Park Blvd., St. Louis, Mo.